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NASA

PNEUMATIC NUTATOR ACTUATOR MOTOR

By

C. N. High, G. R. Howland, J. R. Williamson

Prepared For

NATIONAL AERONAUTICS & SPACE ADMINSTRATION

CONTRACT NAS3-5214

THE Bendix CORPORATION

BENDIX PRODUCTS AEROSPACE DIVISION
SOUTH BEND, INDIANA 46620

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SECOND QUARTERLY REPORT

PNEUMATIC NUTATOR ACTUATOR MOTOR

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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PNEUMATIC NUTATOR ACTUATOR MOTOR

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ABSTRACT

This is the second quarter report of a twelve-month program to design, fabricate and test a prototype pneumatic nutator actuator motor for drum control of a nuclear reactor. The design concept is described in the first report NASA CR-54204 (BPAD-864-15521R).

During the second quarter, all components were fabricated. Photographs of the component parts are shown. Further test results of the breadboard commutation circuit are given.

PNEUMATIC NUTATOR ACTUATOR MOTOR

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SUMMARY

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This report describes the second quarter accomplishments of a twelve-month program to develop a pneumatic actuator motor of a new concept. The actuator motor operates from a pneumatic power supply and produces a high torque, low speed mechanical output proportional to a pneumatic input pressure differential signal. The commutation logic of the motor is accomplished by closed loop fluid interaction (vortex type) devices.

The fabrication status of the mechanical and commutation circuit components is given. Further test results of the breadboard commutation circuit are also presented. The anticipated goals for the third quarter are listed.

author

SECTION 1

INTRODUCTION

The Pneumatic Nutator Actuator Motor is being developed by Bendix Products Aerospace Division under Contract NAS3-5214 for NASA-Lewis Research Center. The purpose of the contract is to build and evaluate a pneumatic actuator motor for control of a nuclear reactor. The required performance is given in the specifications of Contract NAS3-5214. The motor is of a different concept from the conventional gear, vane or piston type actuators. The logic circuits required to operate the motor have no moving parts and are composed of fluid interaction (vortex type) devices.

The analysis and design of the motor was completed in the first quarter. The second quarter was devoted to the manufacture of all component parts, including the commutation plates. Testing of the breadboard commutation circuit, started in the first quarter, was continued to determine the optimum pressure levels in the circuit and the effect of replacing regulated pressure sources by fixed orifices.

Section 2 outlines the present status of the mechanical components. Section 3 discusses the status of the commutation plates and describes the test results of the breadboard circuit. The third quarter goals are given in Section 4.

SECTION 2

MECHANICAL DESIGN

2.1 COMPONENTS

The second quarter of this program was devoted exclusively to fabricating the components and subassemblies which are used to form the complete actuator-motor. Consequently, this section of the report is composed of a series of photographs which show the results of this effort.

Figure 2-1 shows the mounting plate which contains the eight pressure elements and the snubbing mechanism. The snubbing mechanism consists of a brake drum attached to the mounting plate through a torsion bar and further restrained by an adjustable brake band, as indicated in the photograph.

Flexure pivots are used to connect the input gear to the gimbal ring, as shown in Figures 2-2 and 2-3. This subassembly takes the form of a conventional Hooke's joint.

Figures 2-4 through 2-6 show the output shaft, the scram spring, and the output shaft assembly containing the output gear. These three subassemblies constitute the mechanical portion of the actuator-motor and will be assembled into the main housing shown in Figure 2-7.

The complete assembly is shown schematically in Figure 2-8.

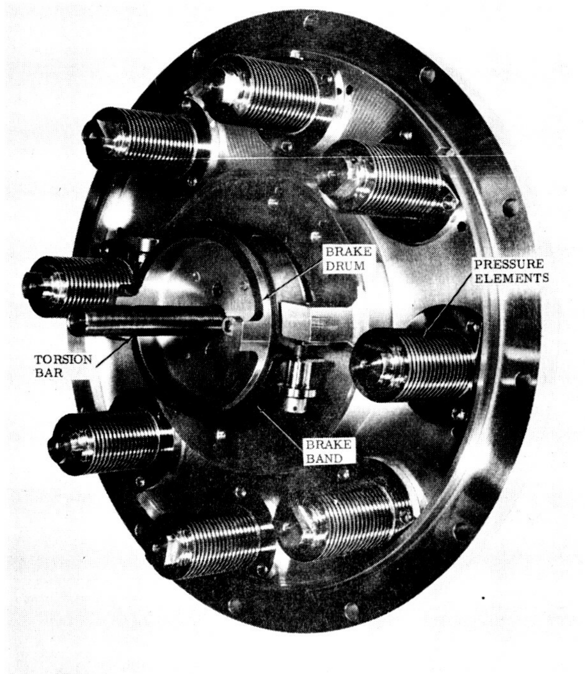


FIGURE 2-1 MOUNTING PLATE CONTAINING PRESSURE ELEMENTS AND SNUBBER MECHANISM

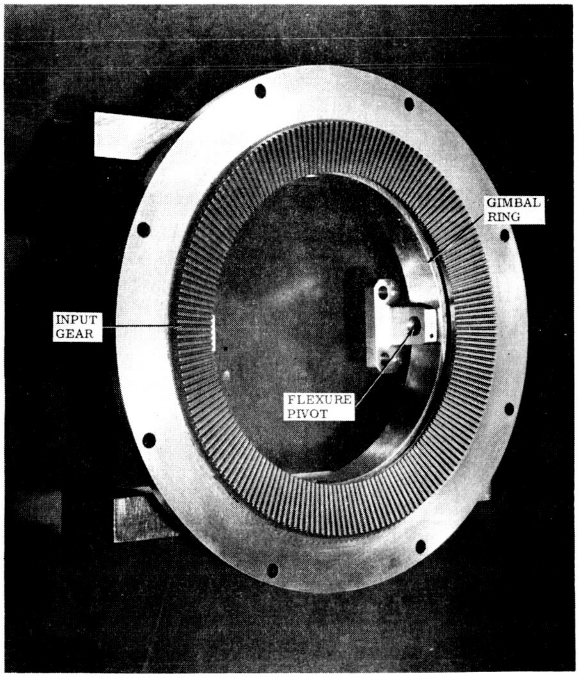


FIGURE 2-2 INPUT GEAR AND GIMBAL RING - FRONT VIEW

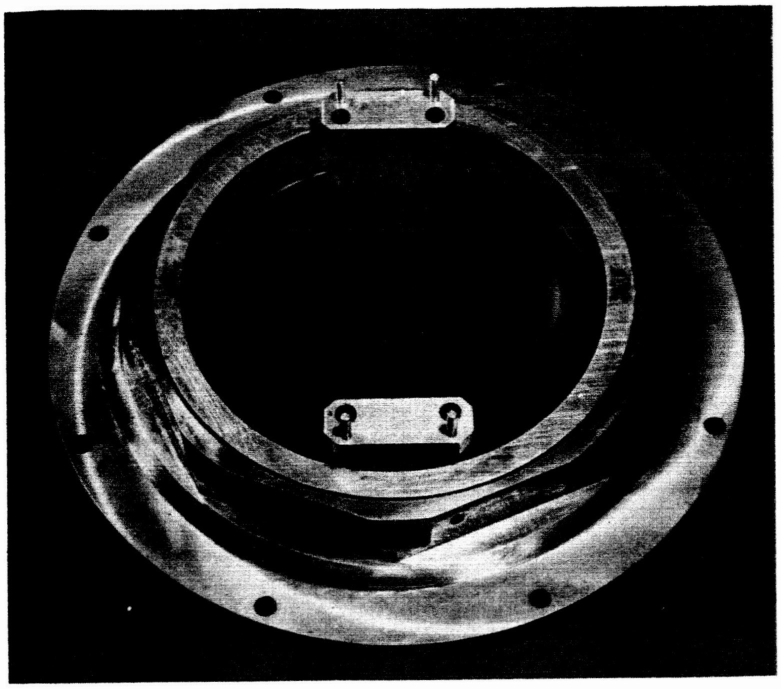


FIGURE 2-3 INPUT GEAR AND GIMBAL RING - REAR VIEW

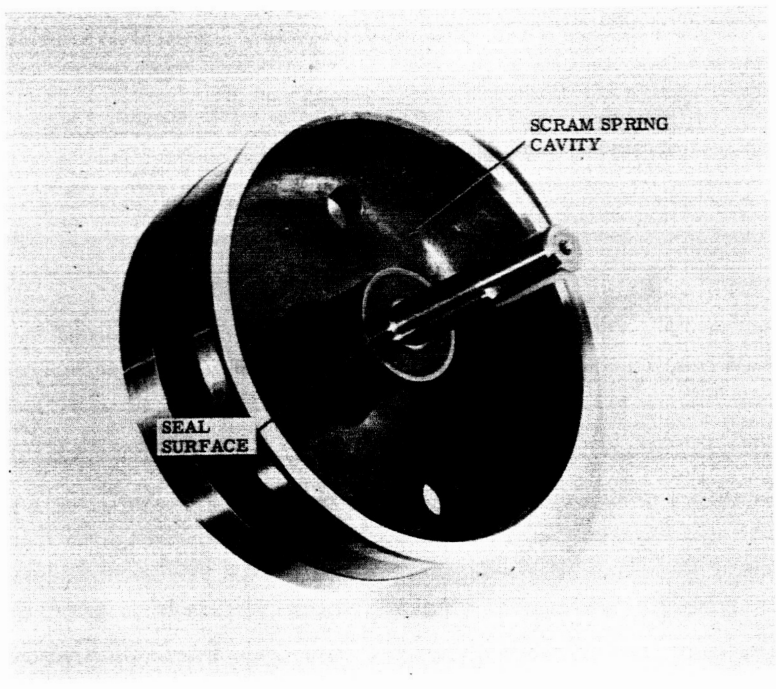


FIGURE 2-4 OUTPUT SHAFT

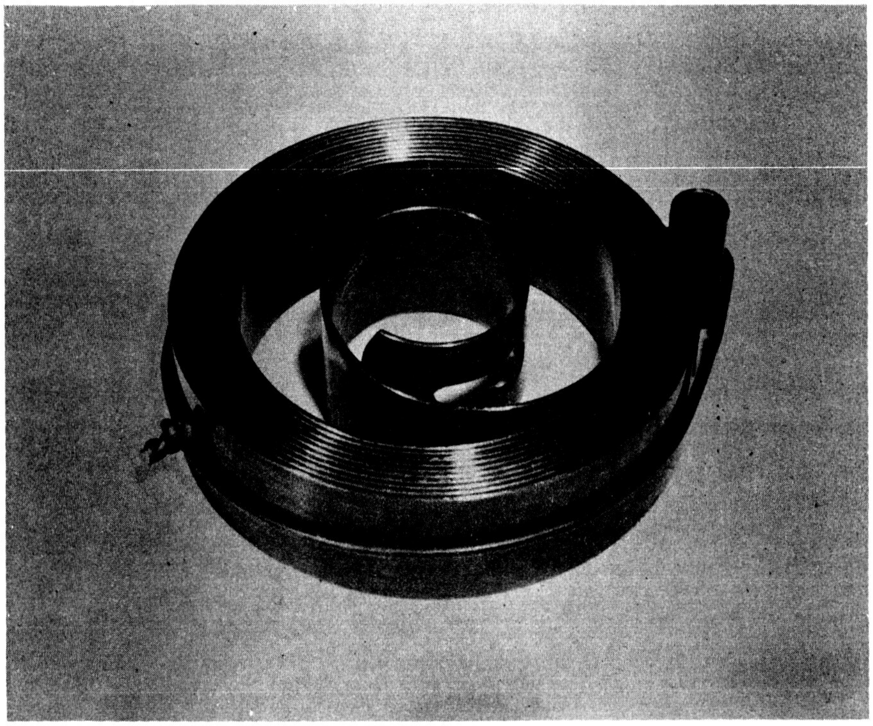


FIGURE 2-5 SCRAM SPRING

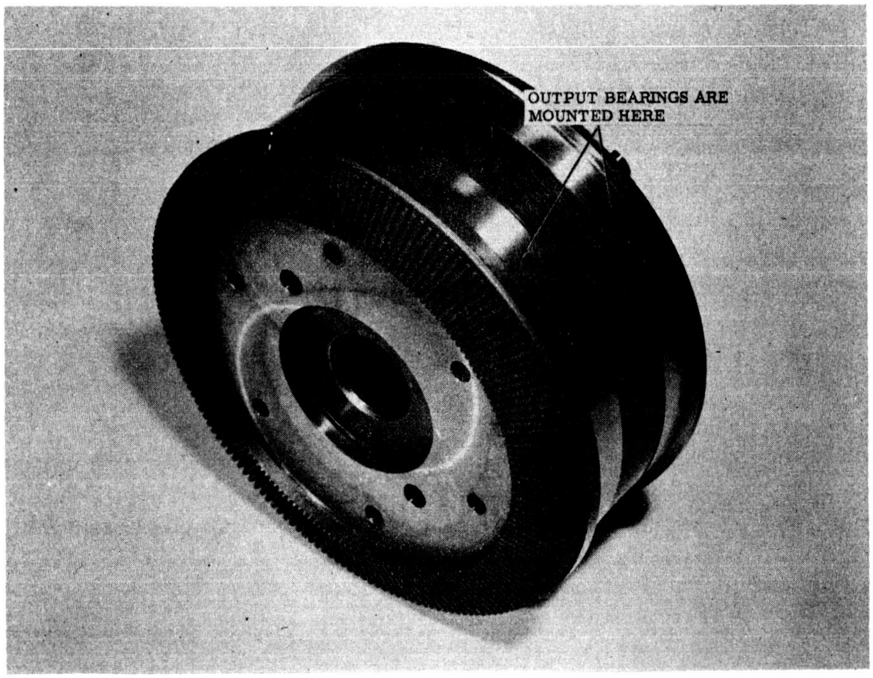


FIGURE 2-6 OUTPUT SHAFT ASSEMBLY CONTAINING OUTPUT GEAR

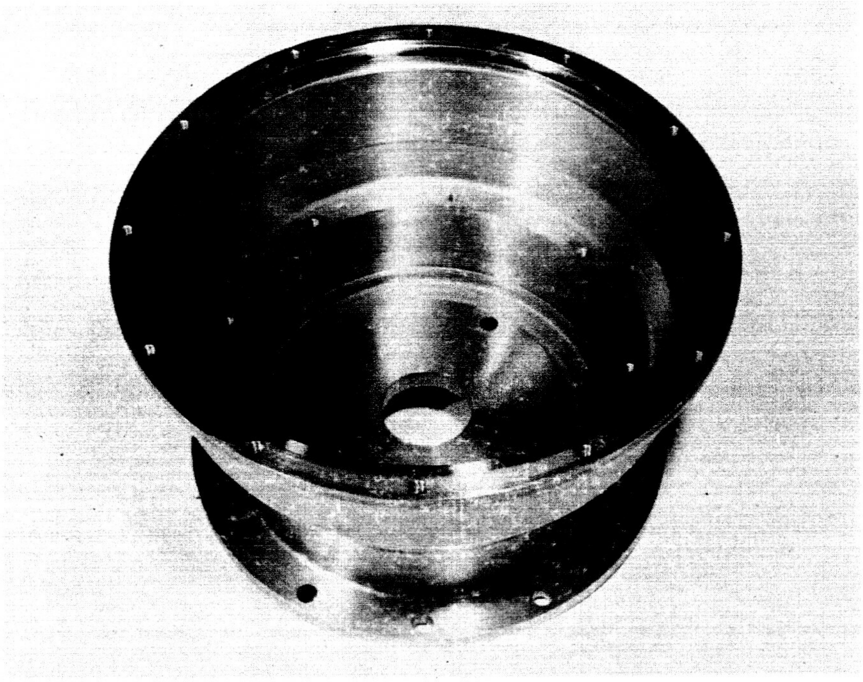


FIGURE 2-7 MAIN HOUSING

2.2 PRESENT STATUS

Due to a rework requirement on the bearings, assembly of the actuator was delayed for approximately one month. At present, all components and subassemblies are complete and assembly has started.

2.3 TEST FIXTURES

All test fixtures and adaptors are complete. The only component outstanding is the potentiometer for position indication on the drum test rig. The potentiometer is expected to be delivered by January 15, 1965.

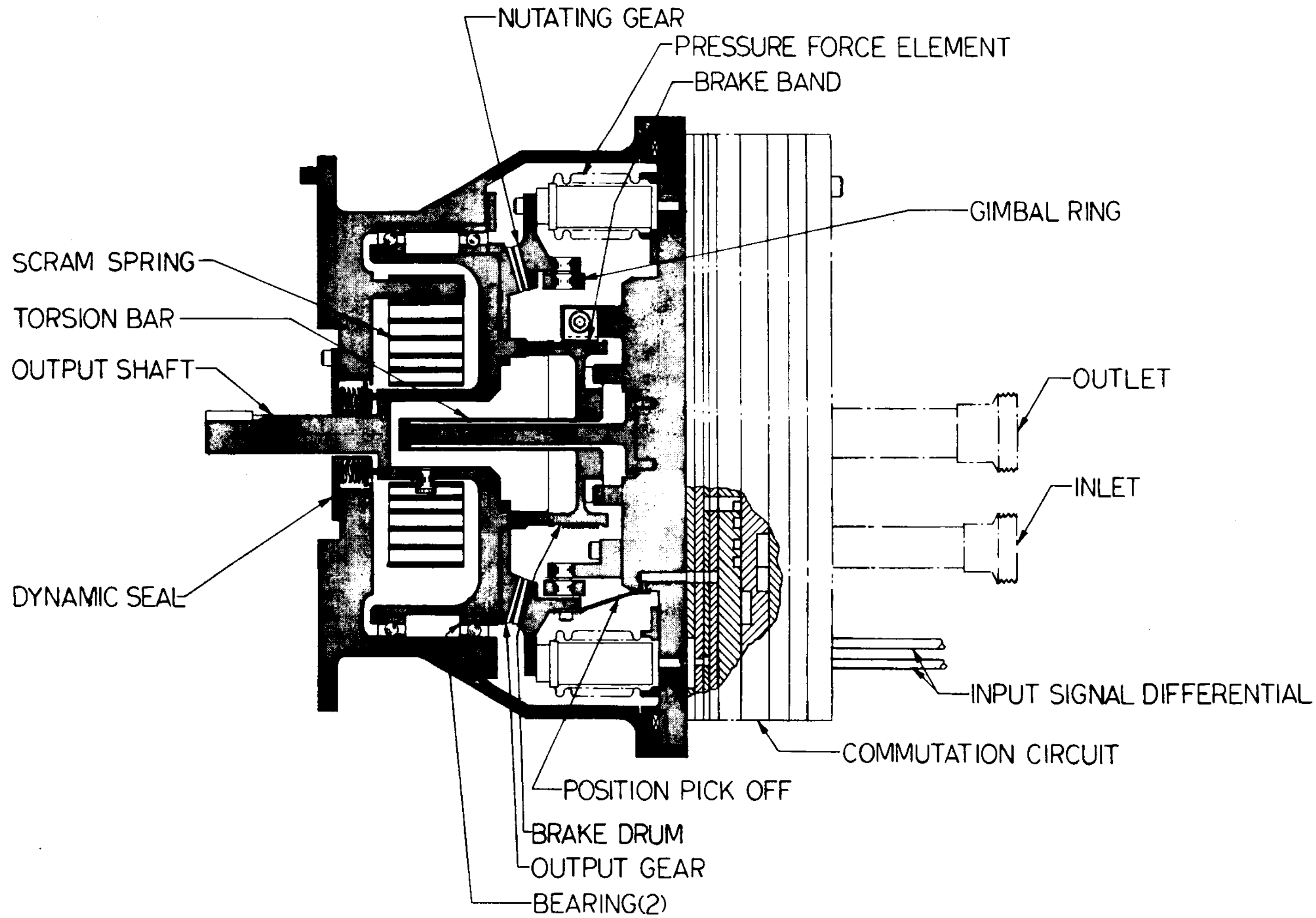


FIGURE 2-8 PNEUMATIC NUTATOR ACTUATOR MOTOR - SCHEMATIC

SECTION 3

COMMUTATION CIRCUIT

3.1 DEVELOPMENT OF COMMUTATION CIRCUIT COMPONENTS

3.1.1 Breadboard Commutation Circuit

Figure 3-1 is a photograph of the breadboard commutation circuit. Figure 3-2(a) illustrates the flow diagram and Figure 3-2(b) the test results using externally regulated supply pressures. Figure 3-3(a) illustrates the flow diagram of and Figure 3-3(b) the test results using fixed-orifice pressure reducers. Significant variations in the selector and power supply pressures occurred in the fixed-orifice circuit test results. It can be seen that these variations affect the power valve output pressures significantly. Figure 3-4(a) illustrates the fixed-orifice circuit employing a vortex valve pressure regulator and a different method of pressure manifolding. The variations in the selector and power supply pressures, shown in Figure 3-4(b), are reduced significantly and the power valve output pressures are comparable to those of the externally regulated commutation circuit. This modification can be readily made to the commutation plates if tests on the circuit indicate the necessity.

The selector valve stage pressure level was reduced from 180 psig to 170 psig. It is anticipated that this pressure can be reduced to 150 psig, with further development. Lowering the selector pressure level reduces the pressure recovery requirements of the directional amplifier.

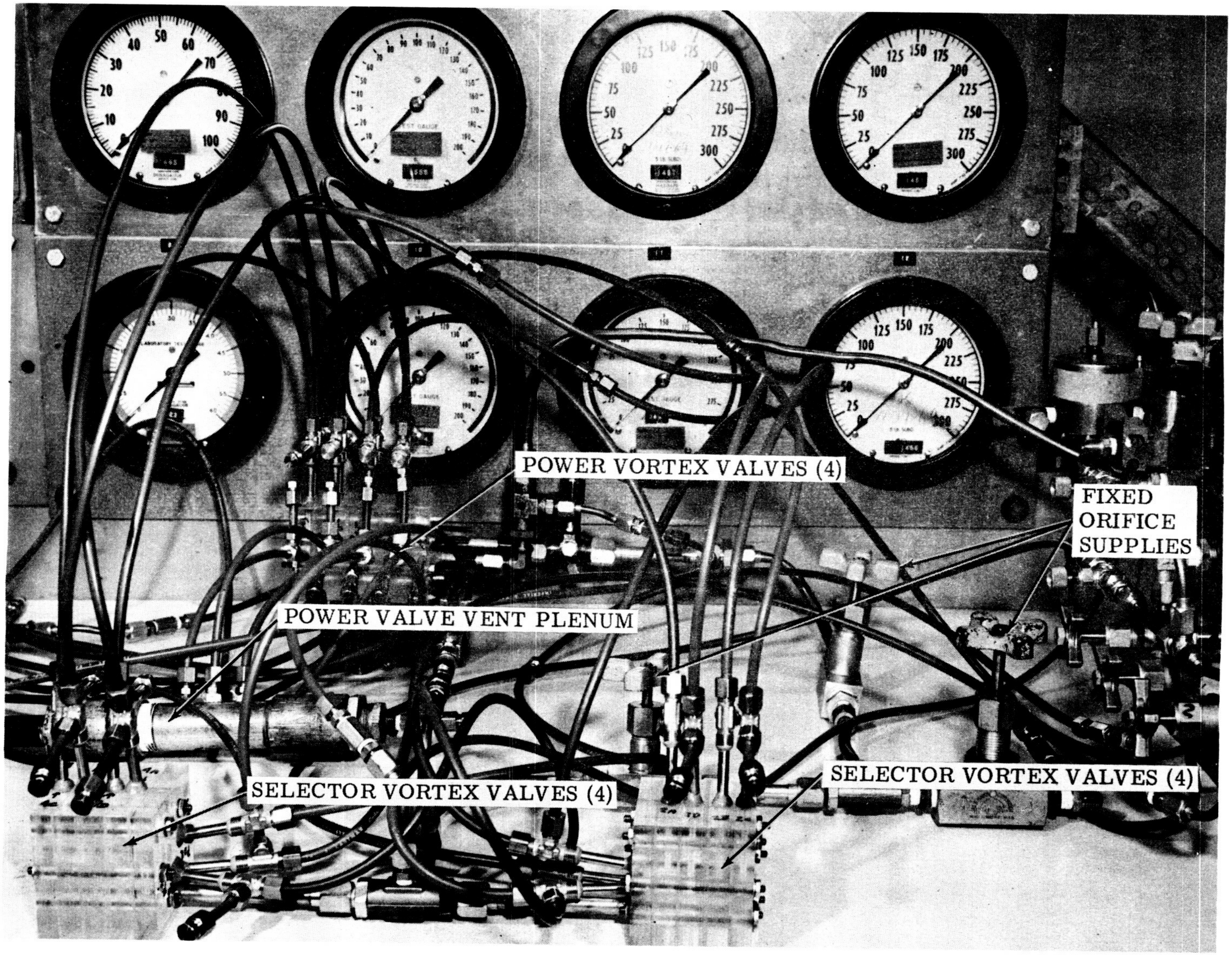
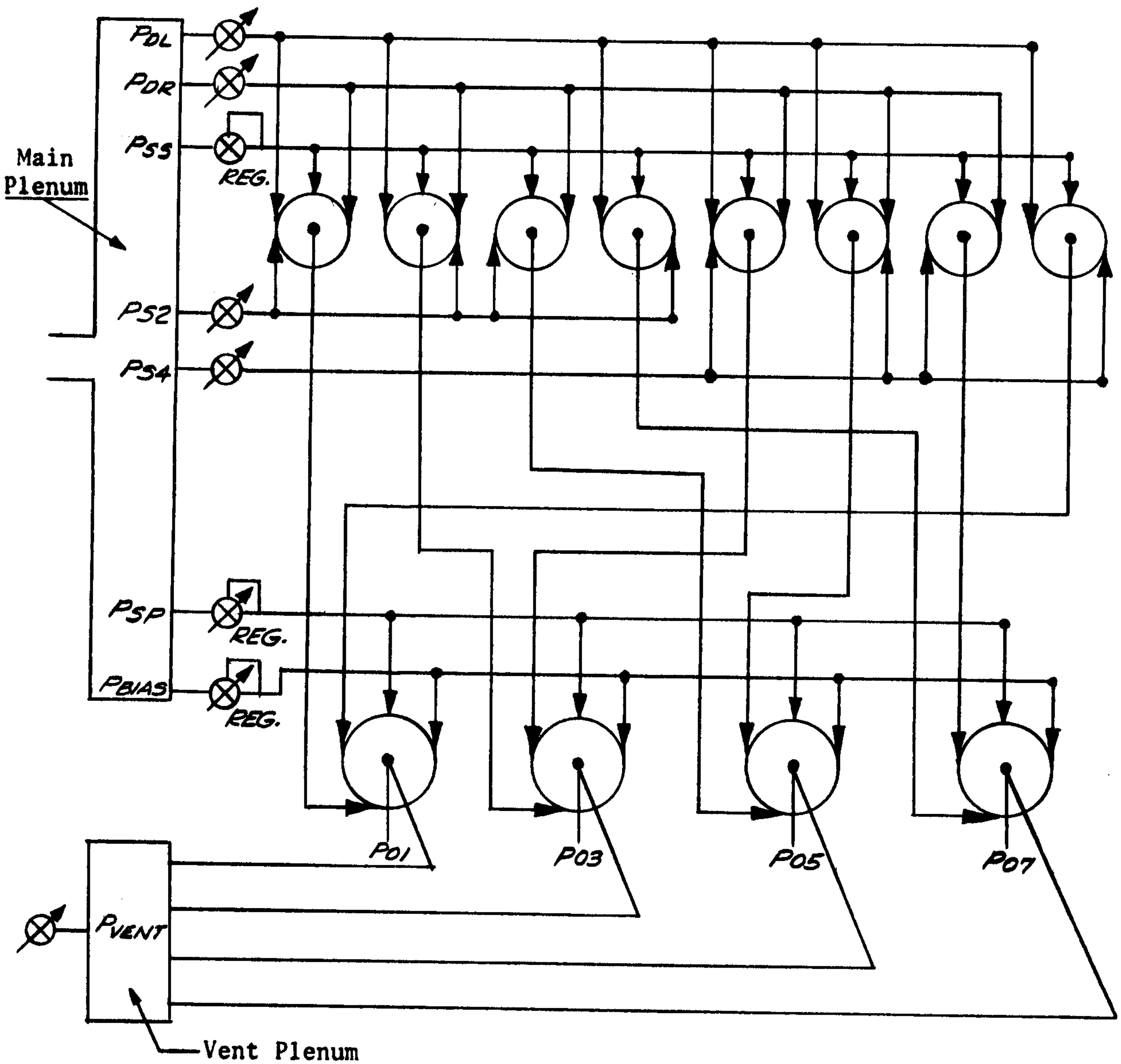


FIGURE 3-1 MODEL COMMUTATION CIRCUIT



P_{D_L} - Left Directional Pressure
P_{D_R} - Right Directional Pressure
P_{s_2} - Position Pick-Off Signal Pressure 2
P_{s_4} - Position Pick-Off Signal Pressure 4
P_{Bias} - Power Valve Bias Pressure
P_{s_s} - Selector Valve Supply Pressure
P_{s_p} - Power Valve Supply Pressure
P_o - Power Valve Output Pressure (To Bellows)

FIGURE 3-2(a) MODEL COMMUTATION CIRCUIT - EXTERNAL REGULATION

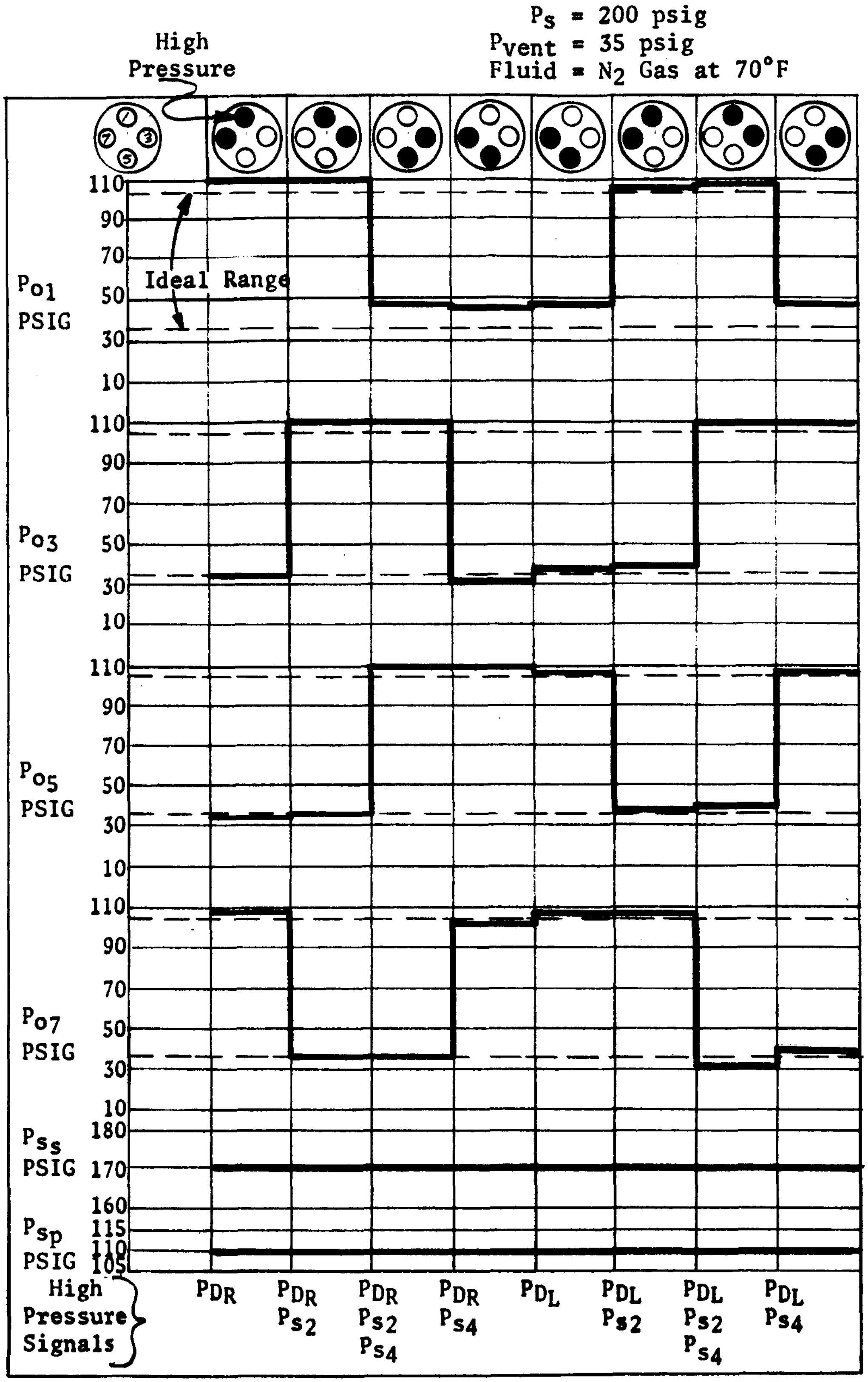


FIGURE 3-2(b) MODEL COMMUTATION CIRCUIT - EXTERNAL REGULATION

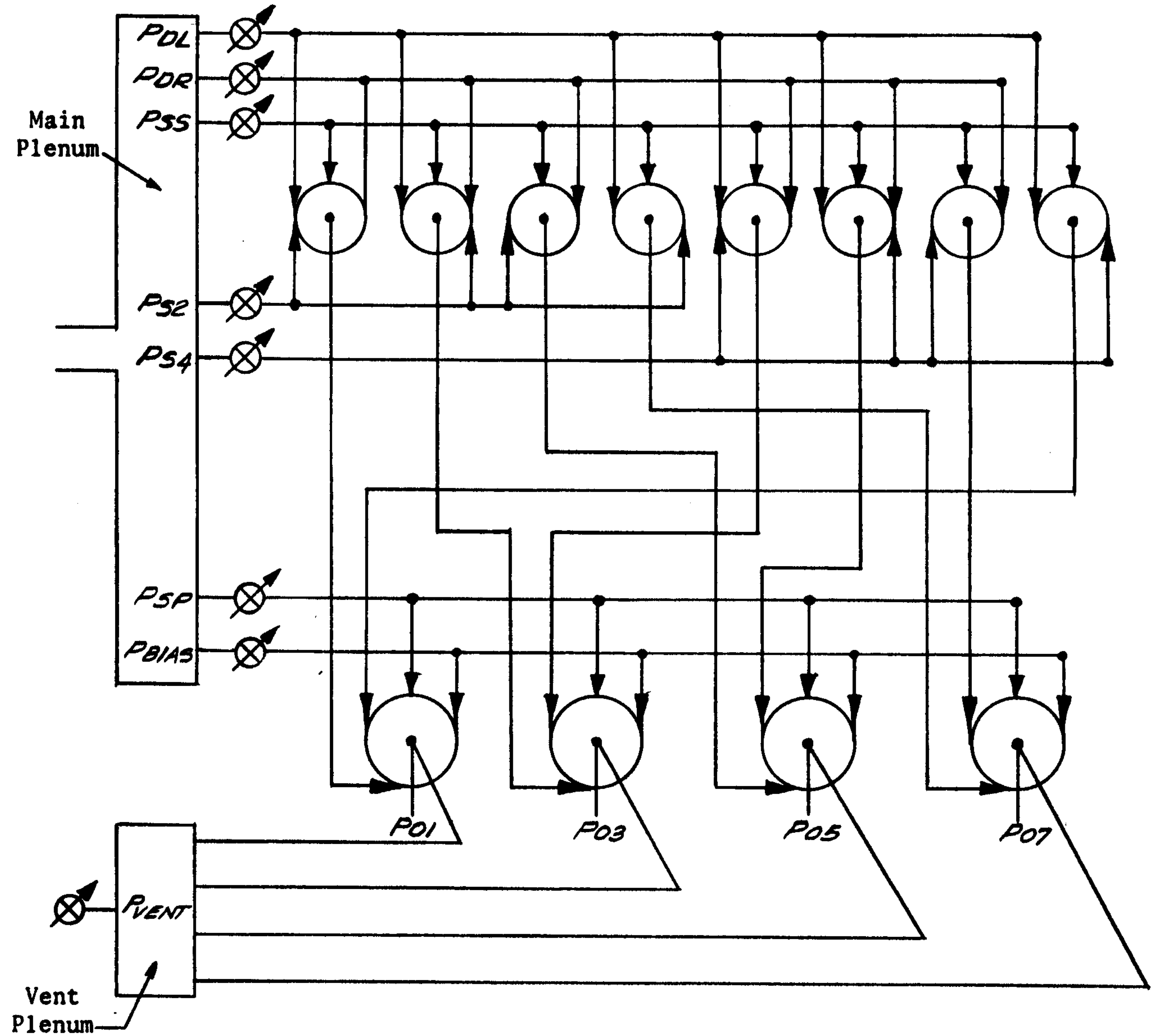


FIGURE 3-3(a) MODEL COMMUTATION CIRCUIT - FIXED ORIFICES

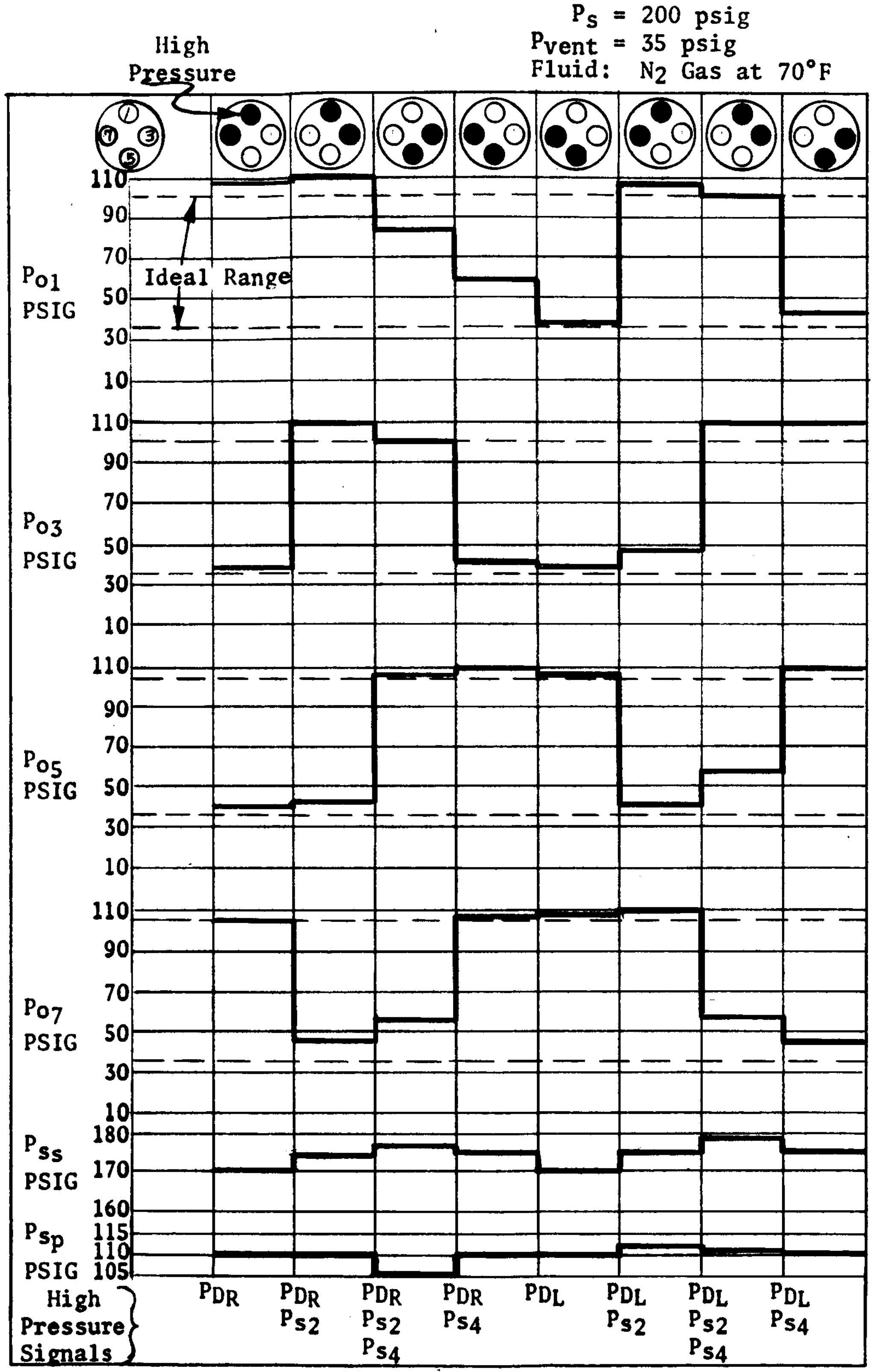


FIGURE 3-3(b) MODEL COMMUTATION CIRCUIT - FIXED ORIFICES

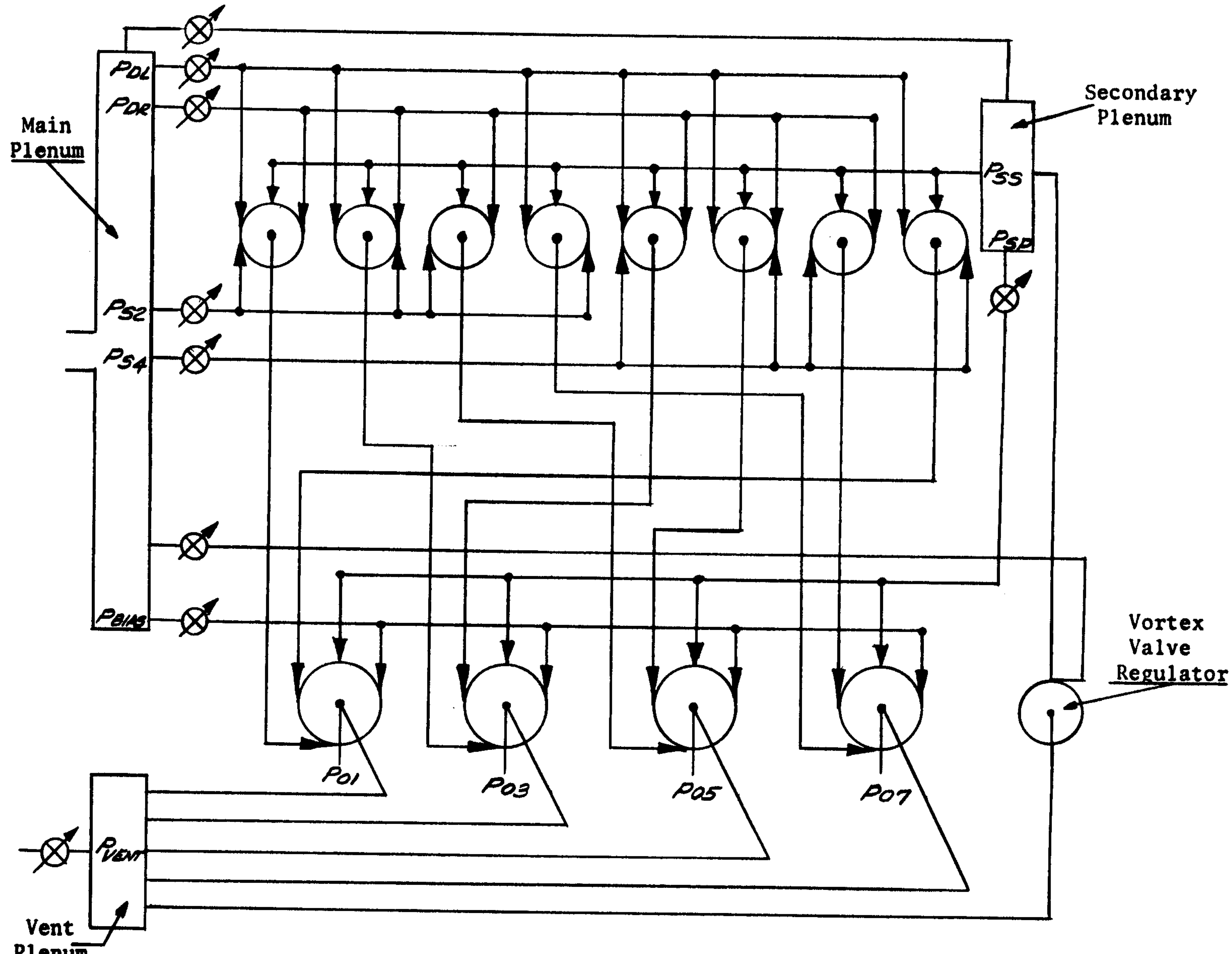


FIGURE 3-4(a) MODEL COMMUTATION CIRCUIT - FIXED ORIFICES
WITH INTERNAL REGULATION

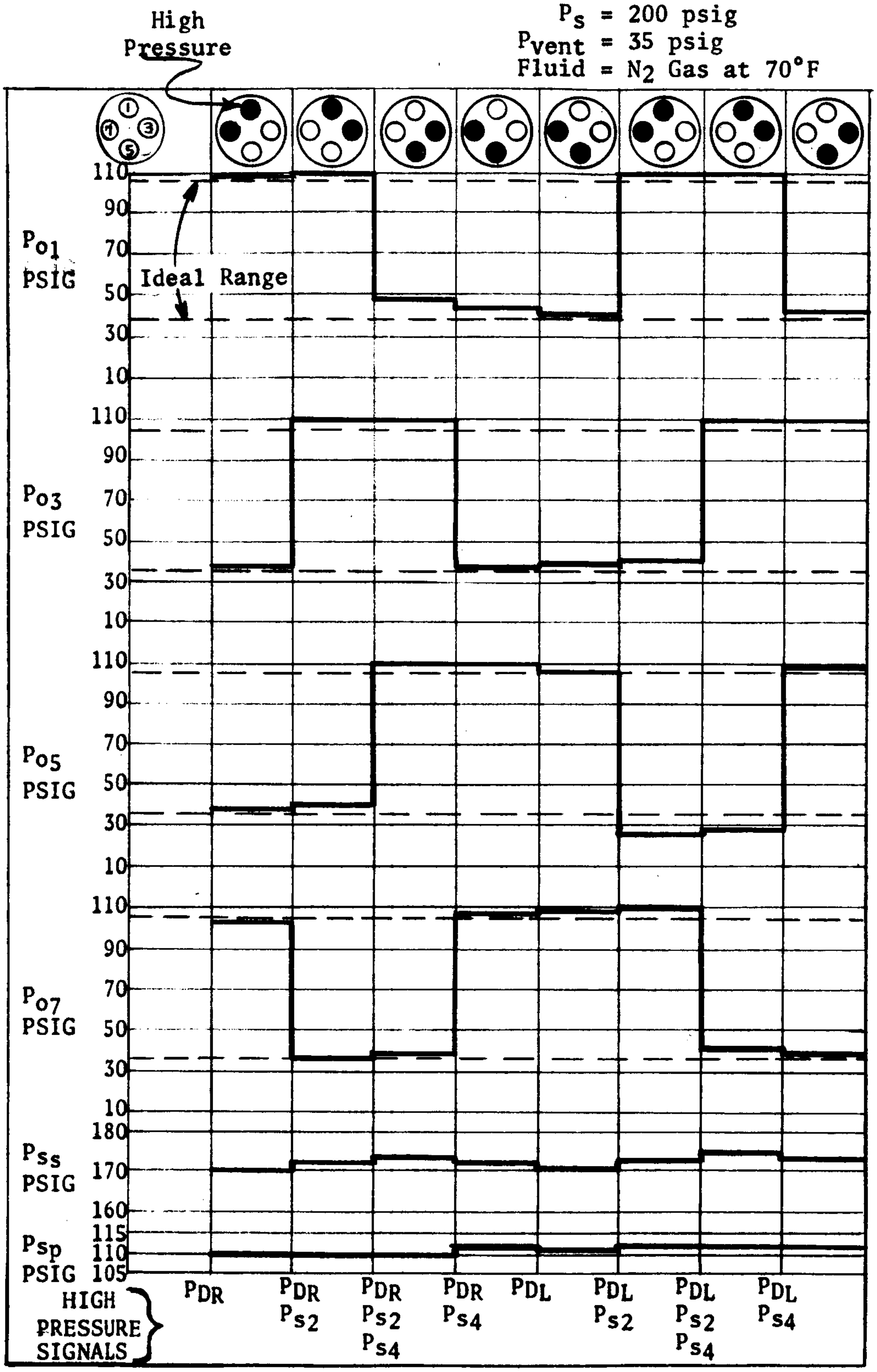


FIGURE 3-4(b) MODEL COMMUTATION CIRCUIT - FIXED ORIFICES WITH INTERNAL REGULATION

3.1.2 Directional Amplifier

Bistable jet-on-jet amplifiers have been obtained from the Bendix Research Laboratories Division and the Bendix Sheffield Division for evaluation tests and compatibility with the breadboard commutation circuit. Initial calibration has been performed with a 15 psig supply pressure and atmospheric vents. Further testing will be done with the vents back-pressured to give a receiver pressure of 150 psig. If stable latching can be maintained, the bistable unit will be incorporated with the pressure error valve and the breadboard circuit.

3.1.3 Pressure Error Valve

Development has been started on the design of a low gain vortex summing valve for use as the pressure error valve. Minimum pressure gain is required to reduce the sensitivity requirements of the directional amplifier and avoid potential noise problems in the command pressure signals.

Test vortex valves were fabricated in which the control port was canted from the chamber tangent to an angle of 10°, 20°, and 30° toward the radial. A calibration of the valves is given in Figure 3-5. It can be seen that a gain improvement resulted.

Figure 3-6(a) illustrates the results of moving the control port nearer the outlet. The gain for the conventional valve, Curve A, is 40. (All pressure gains are taken over the linear portions of the curves.) The pressure Curve B is offset with respect to Curve A. It is possible that a higher control pressure is needed to compensate for a smaller effective swirl diameter.

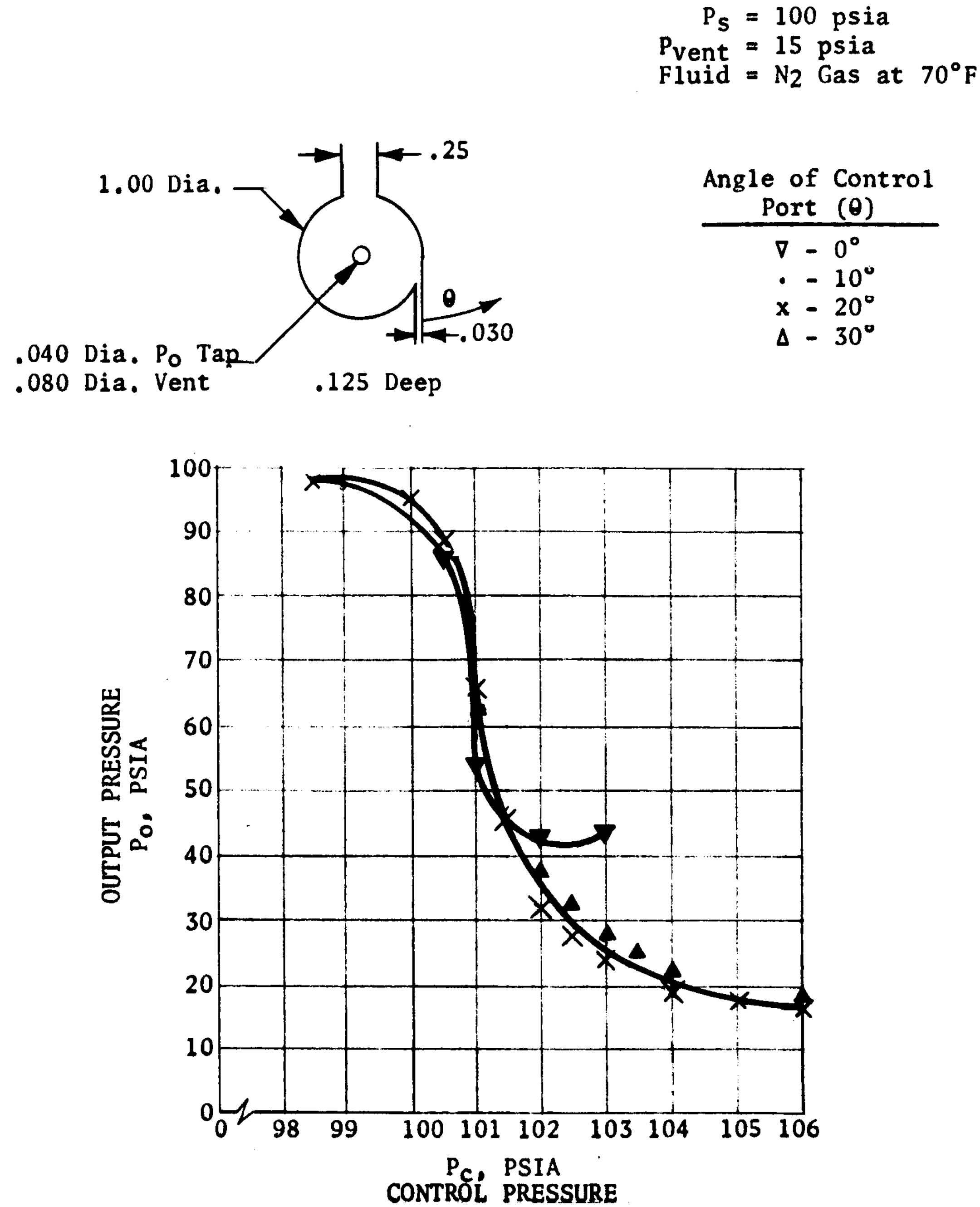


FIGURE 3-5 PRESSURE CURVES FOR VORTEX VALVES WITH DIFFERENT CONTROL PORT ANGLES

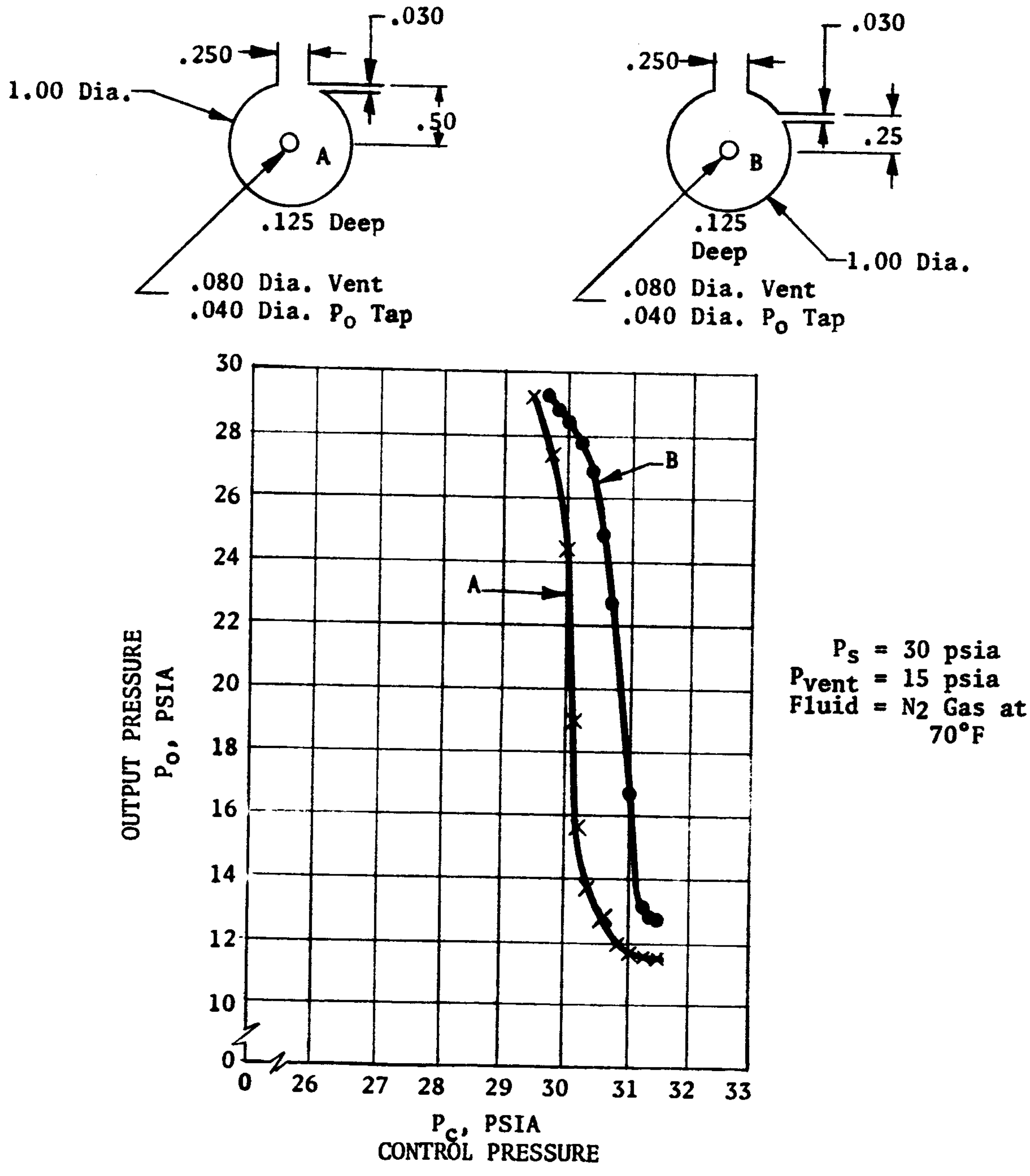


FIGURE 3-6(a) PRESSURE CURVES FOR VORTEX VALVES WITH CONTROL PORTS ENTERING THE CHAMBERS AT DIFFERENT RADII

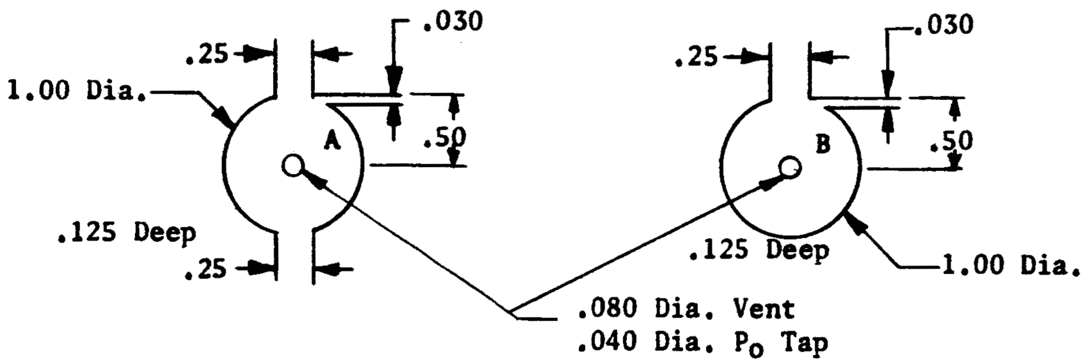
Figure 3-6(b) shows the effect of adding another supply port to the chamber. The gain of each valve is 40. However, the initial control and P_o pressure for valve B is lower than for valve A. This is most likely due to the fact that the supply flow velocity in valve B is higher than in valve A and that there are more turbulent losses in valve B.

Figure 3-6(c) illustrates the effect of introducing control flow to the supply flow before both flows reach the mixing chamber. The gains of valves A and B are 21 and 12, respectively, as compared to 40 for the conventional valve. There is an increase in the minimum P_o pressure as the control port is moved farther up the supply port. Also, the minimum P_o pressure occurs before the supply flow is shut off.

Figure 3-6(d) shows that by introducing a spoiler into the mixing chamber, different gains can be accomplished. The gains for the three curves shown are 40, 8, and 2.

Of the designs tested, the most promising for the pressure error valve application is the spoiler design, for the following reasons: (1) low gains are easily attained, (2) the gain is easily adjustable, and (3) a high minimum P_o is associated with a low gain. This is desirable because if the valve is saturated with a high pressure error, the output pressure will not decrease below a given level.

Further tests will be conducted employing a restriction in the valve inlet.



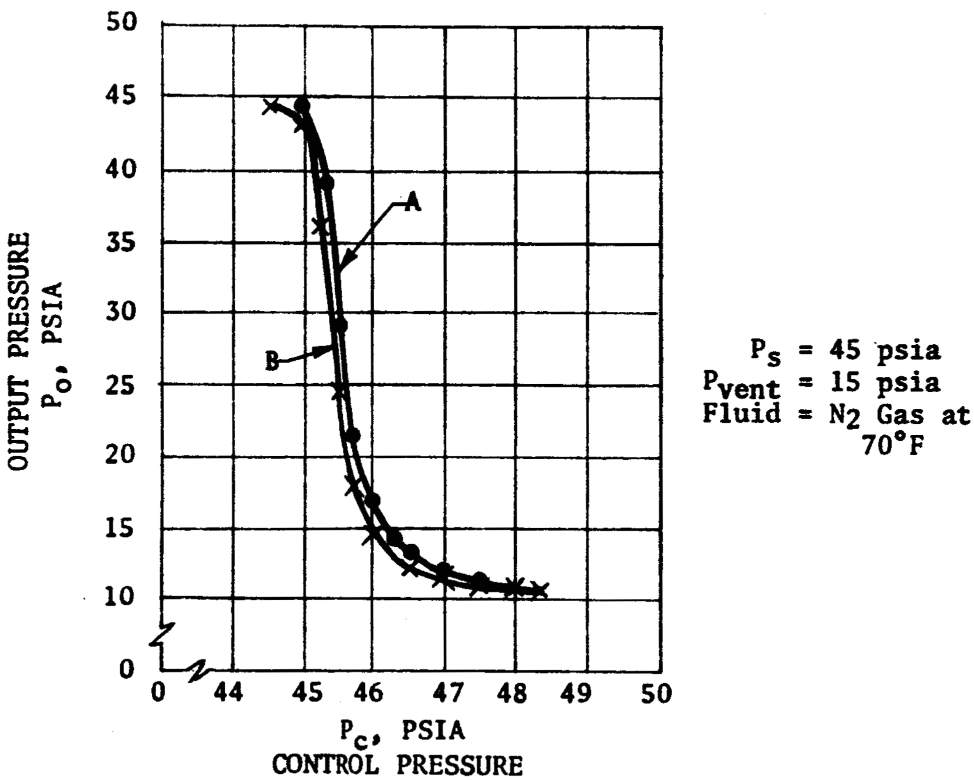
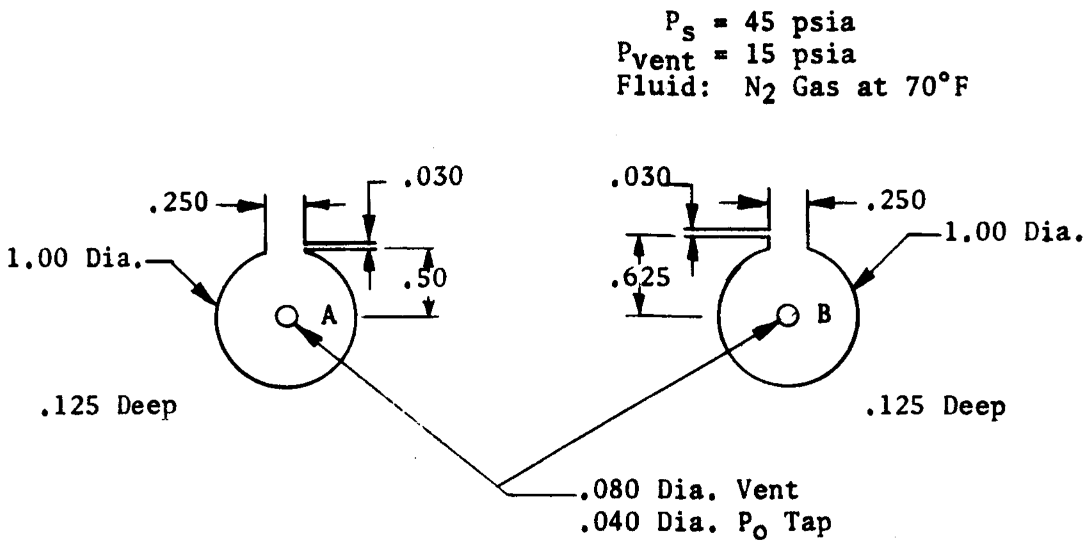


FIGURE 3-6(b) PRESSURE CURVES FOR VORTEX VALVES WITH A DIFFERENT NUMBER OF SUPPLY PORTS



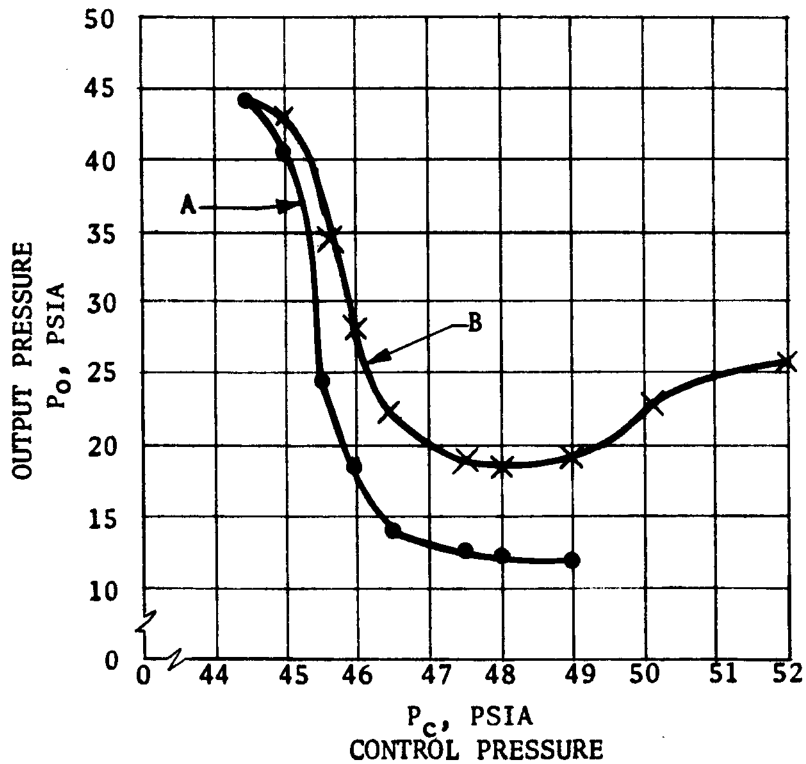


FIGURE 3-6(c) PRESSURE CURVES FOR VORTEX VALVES WITH CONTROL PORTS ENTERING THE SUPPLY PORTS AT DIFFERENT POINTS

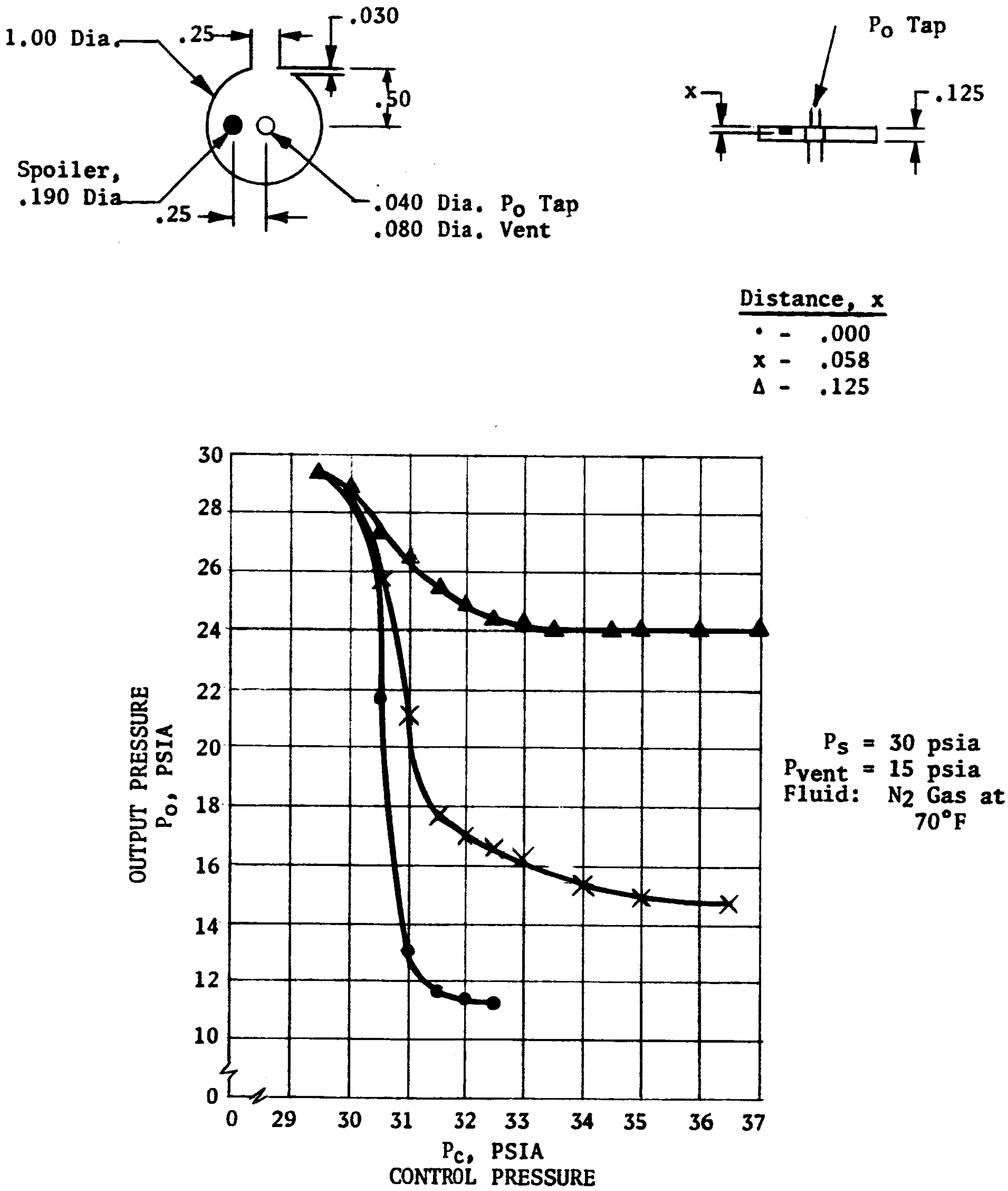


FIGURE 3-6(d) PRESSURE CURVES FOR VORTEX VALVE USING "SPOILER" SET AT VARYING DEPTHS

3.2 FABRICATION OF CIRCUIT PLATES

3.2.1 Commutation Plates

Fabrication of the actuator commutation plates is complete except for cutting the control slots in the selector and power valve plates and grinding all plate faces.

Figures 3-7 through 3-13 are photographs of plates 2 through 7. Plates 1 and 10 were not available for photographing. Plates 8 and 9 have been replaced by one plate to which the pressure error valve and directional amplifier will be attached. The plate is also being machined at present. Plates 1 through 9 make up the commutation circuit shown in Figure 1-5-1 of the first quarterly report.

3.2.2 Test Plates

Figures 3-14 through 3-16 show the test plates which will be used in conjunction with the commutation plates for circuit testing only. These plates incorporate pressure taps for measuring the critical pressures in the circuit. After calibration and circuit checkout, the test plates are removed. Fabrication of the test plates is approximately 90% complete.

3.3 SEAL TEST FIXTURE

The annular grooved sealing plates described in the first quarterly report were relapped and silver plated. The sealing procedure used in the previous test was repeated. Again, no leakage occurred and visual inspection of the mating faces indicated that the seal was uniform.

The duplication of this test indicates that the silver furnace bond will provide a reliable method of sealing the commutation plates.

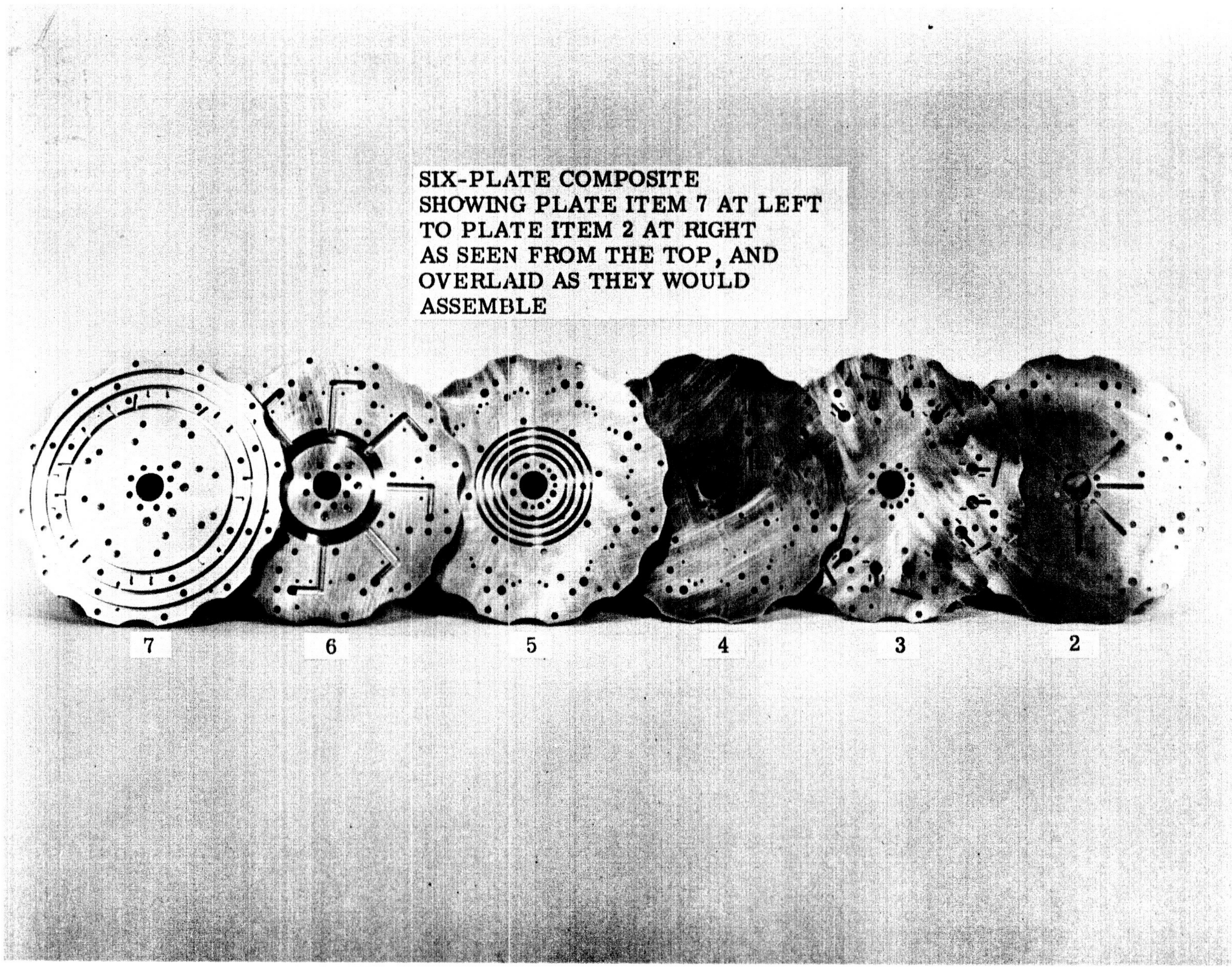


FIGURE 3-7 COMMUTATION PLATES

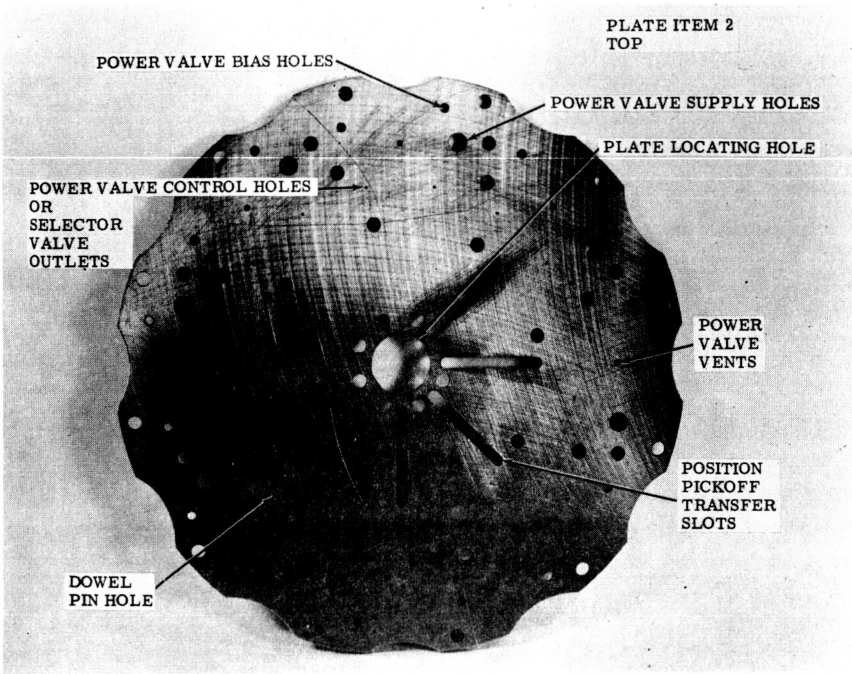


FIGURE 3-8(a) PLATE ITEM 2 - TOP

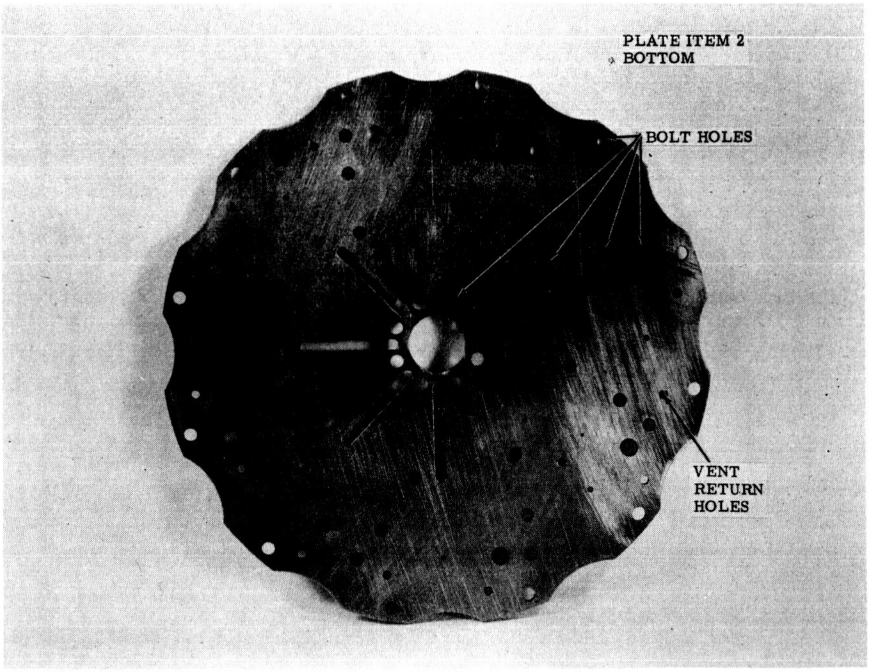


FIGURE 3-8(b) PLATE ITEM 2 - BOTTOM

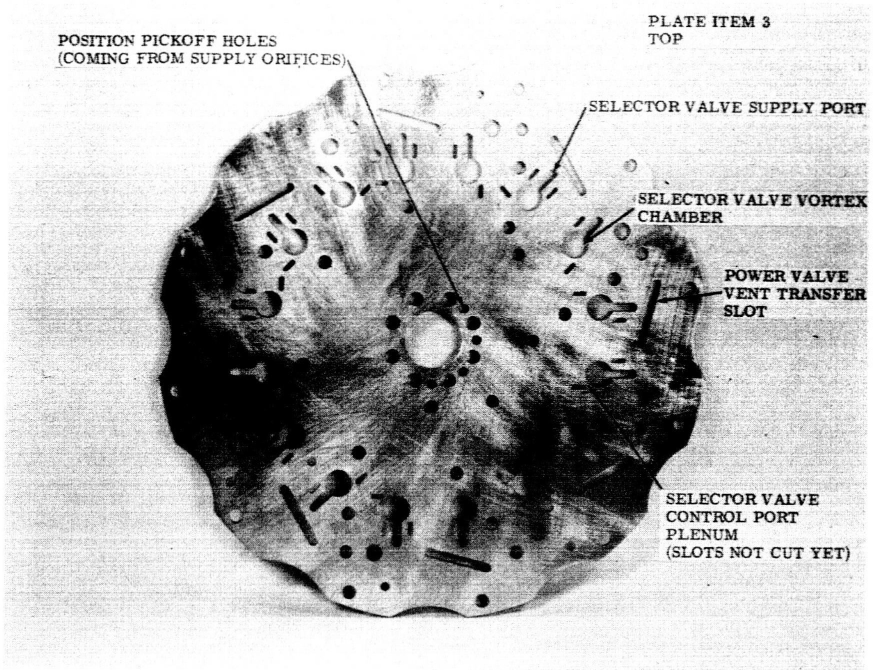


FIGURE 3-9(a) PLATE ITEM 3 - TOP

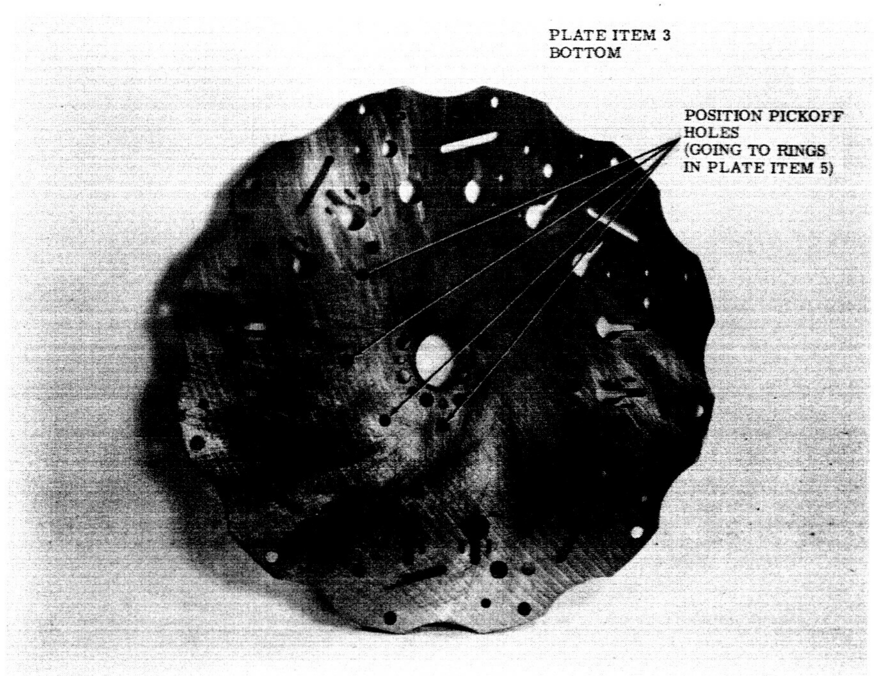


FIGURE 3-9(b) PLATE ITEM 3 - BOTTOM

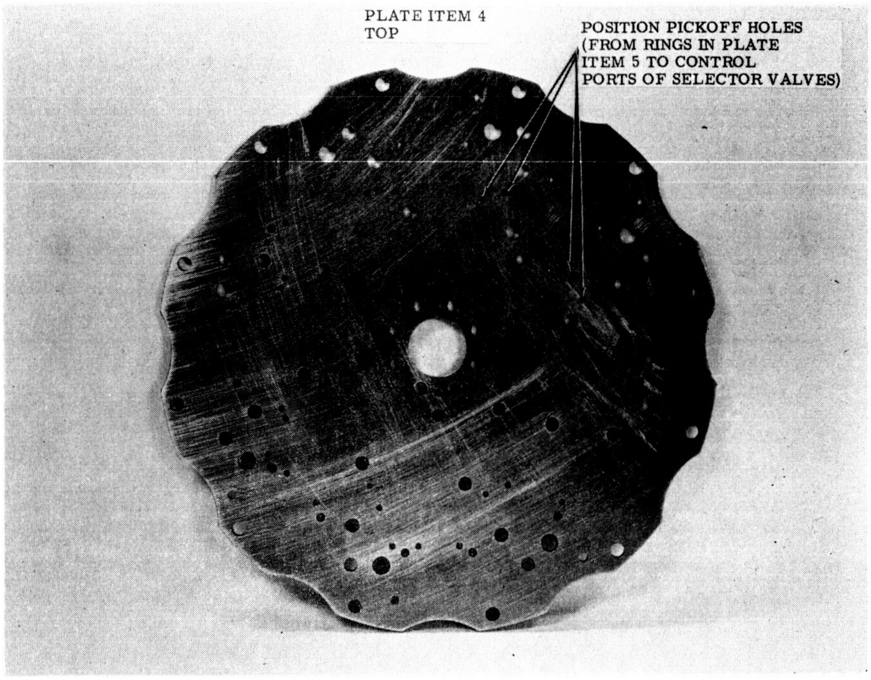


FIGURE 3-10(a) PLATE ITEM 4 - TOP

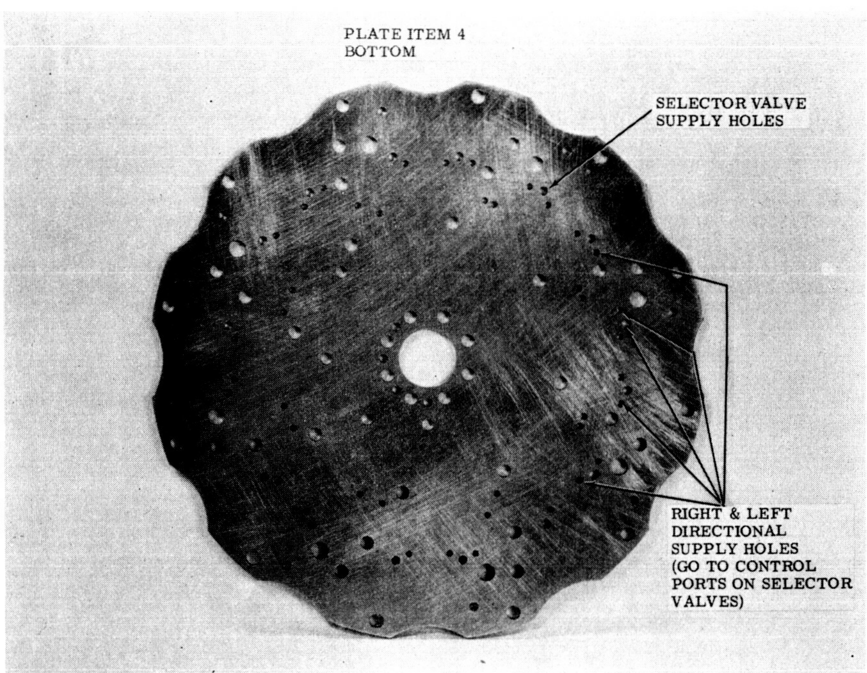


FIGURE 3-10(b) PLATE ITEM 4 - BOTTOM

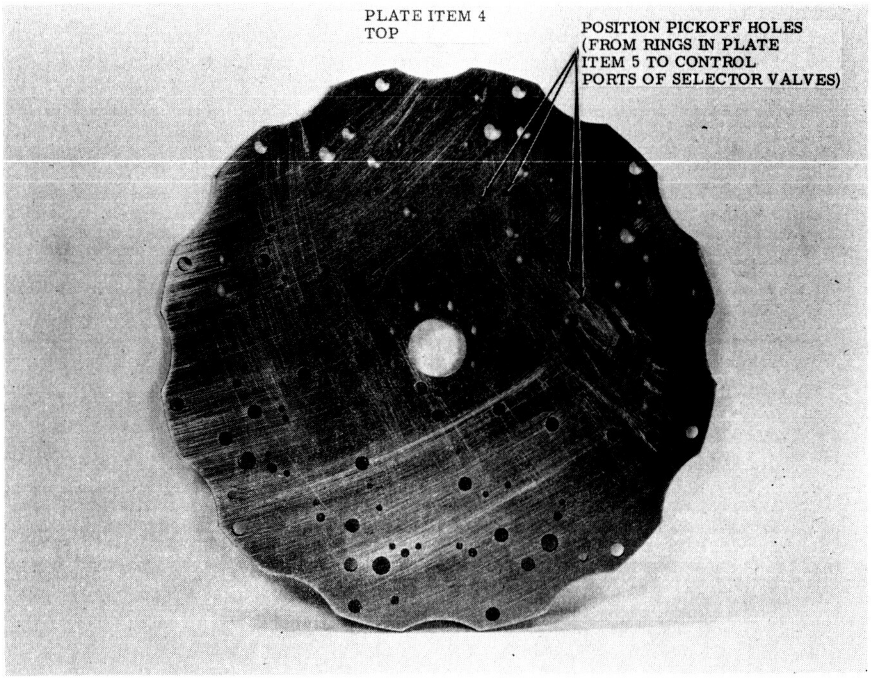


FIGURE 3-10(a) PLATE ITEM 4 - TOP

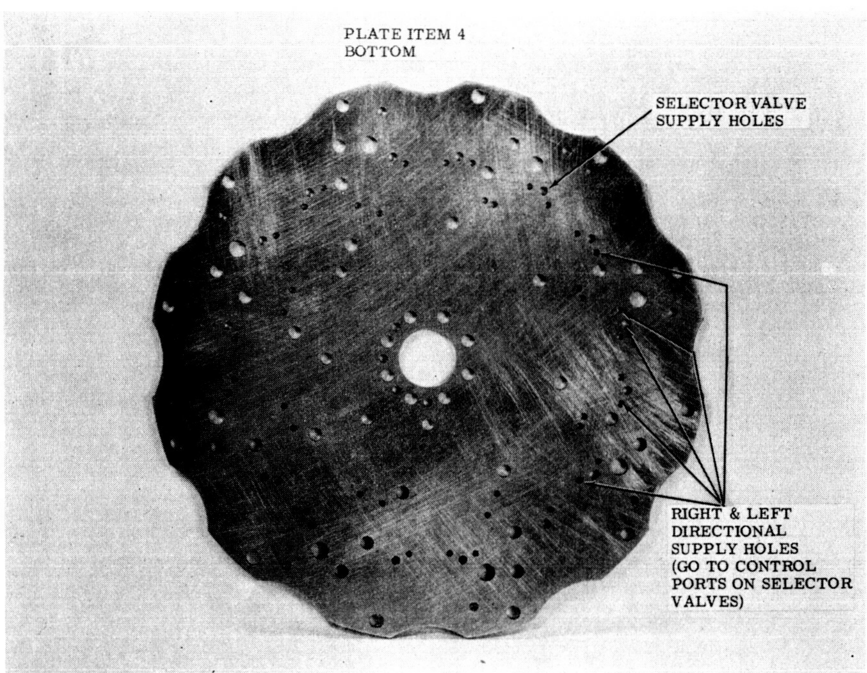


FIGURE 3-10(b) PLATE ITEM 4 - BOTTOM

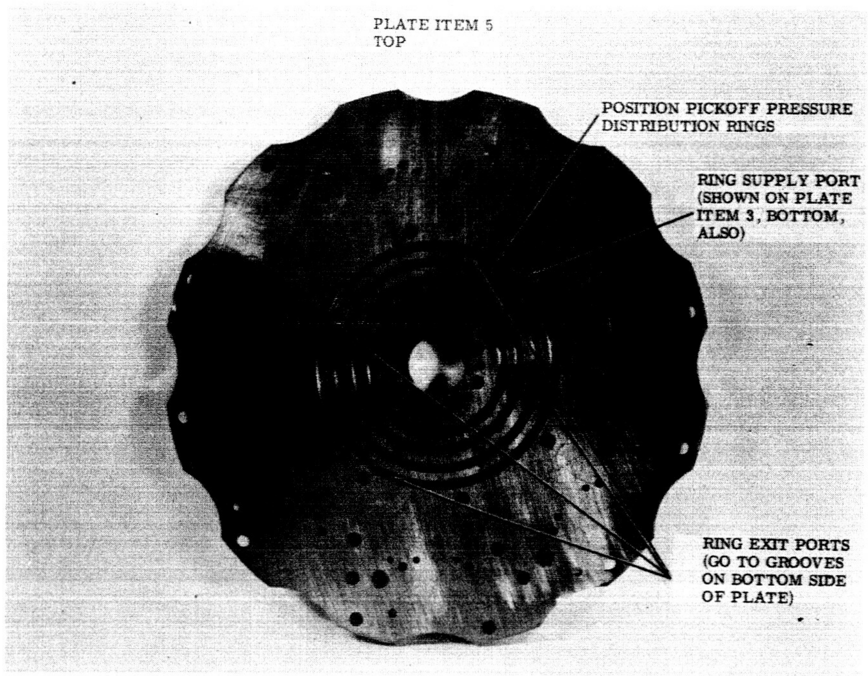


FIGURE 3-11(a) PLATE ITEM 5 - TOP

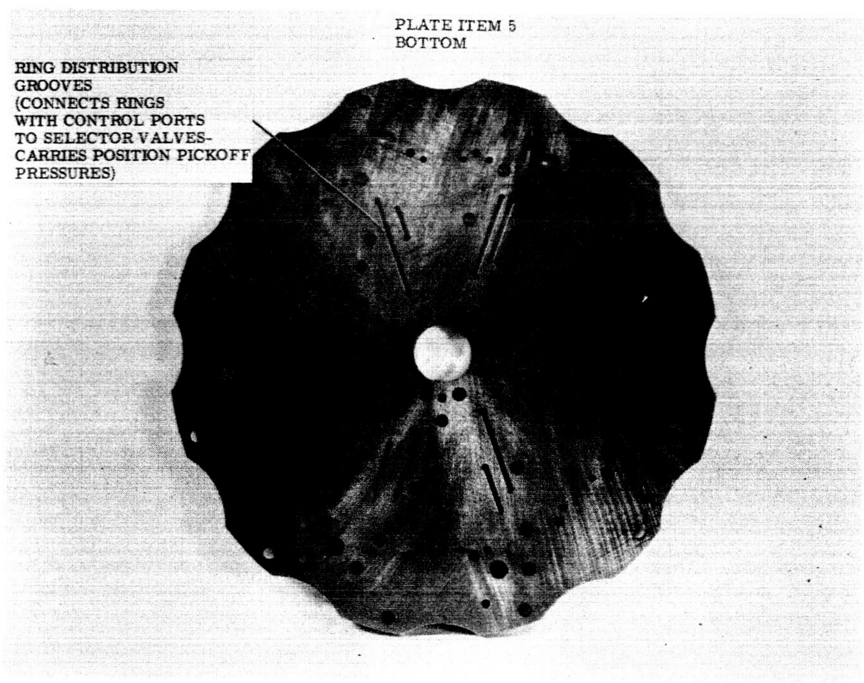


FIGURE 3-11(b) PLATE ITEM 5 - BOTTOM

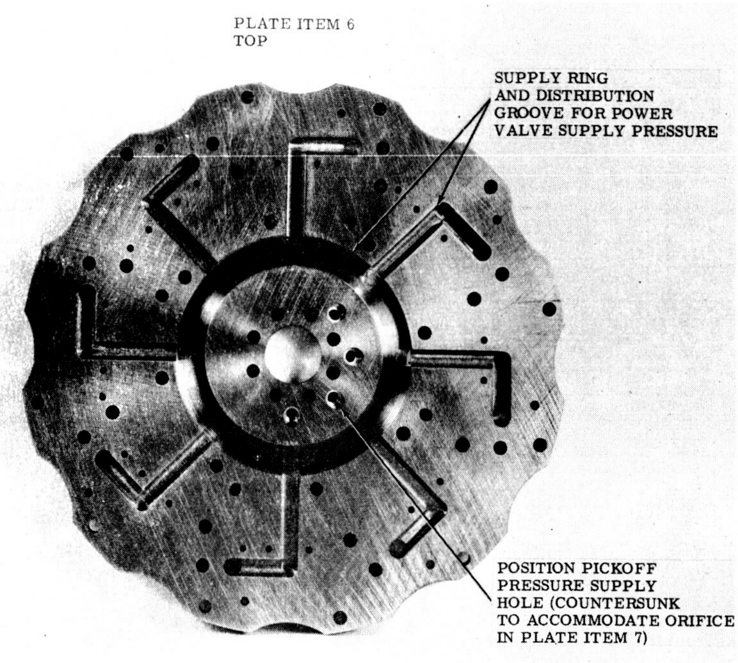


FIGURE 3-12(a) PLATE ITEM 6 - TOP

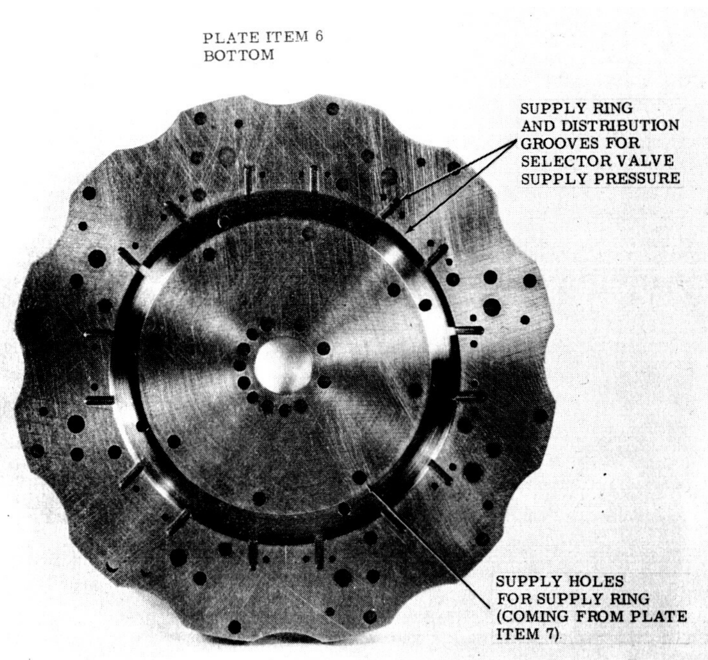


FIGURE 3-12(b) PLATE ITEM 6 - BOTTOM

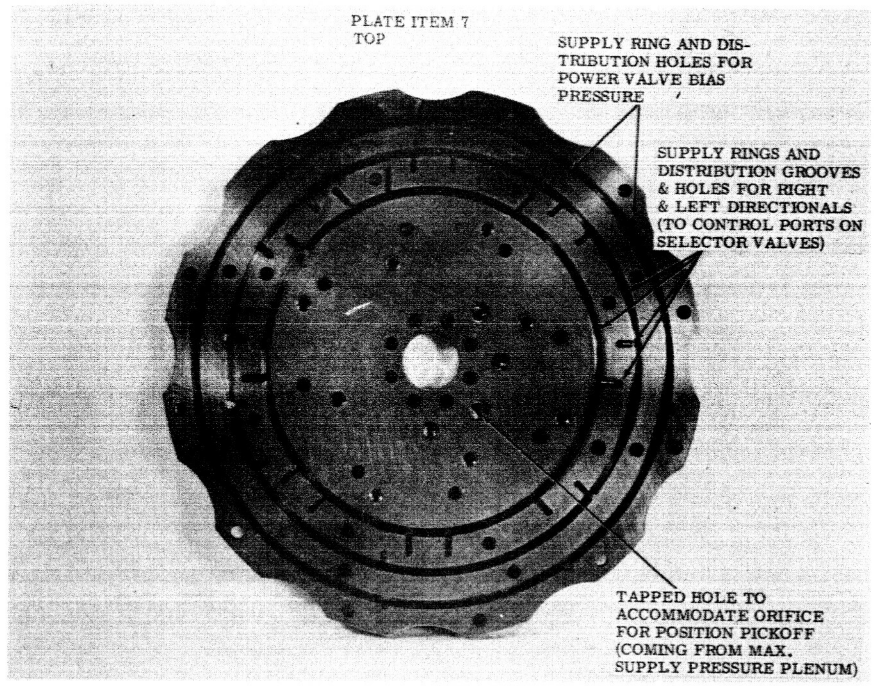


FIGURE 3-13(a) PLATE ITEM 7 - TOP

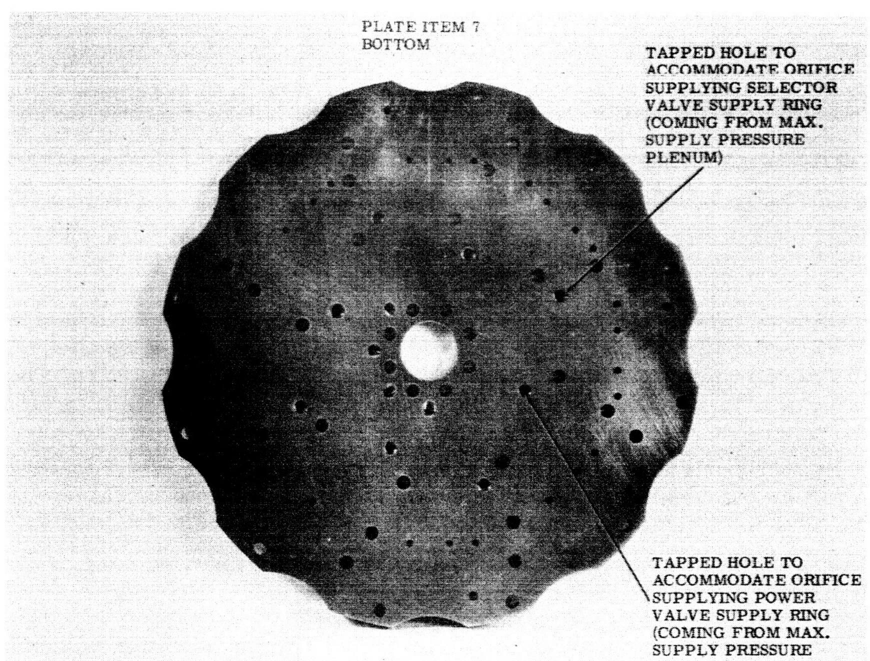


FIGURE 3-13(b) PLATE ITEM 7 - BOTTOM

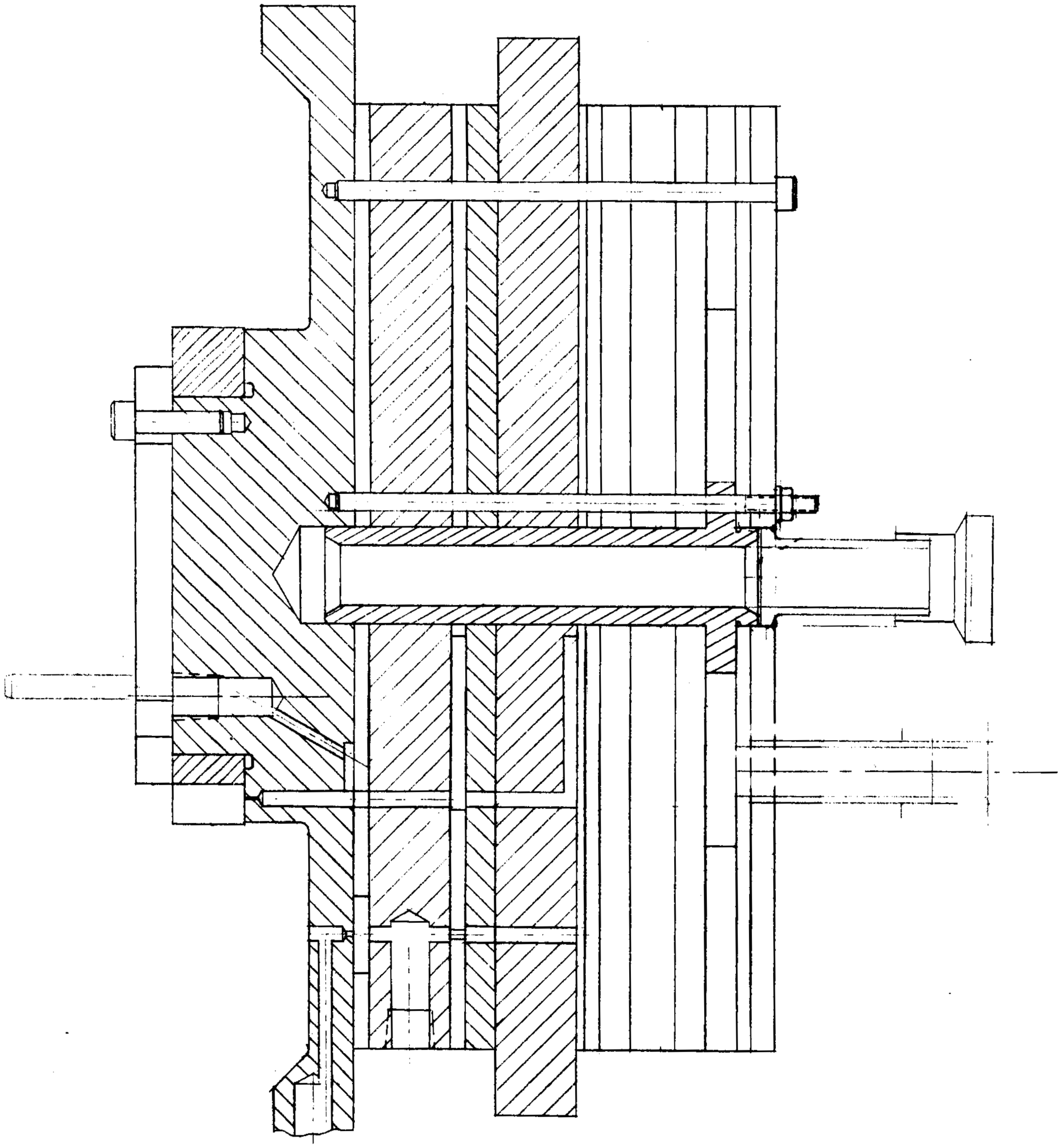


FIGURE 3-14 ASSEMBLY OF COMMUTATION AND TEST PLATES

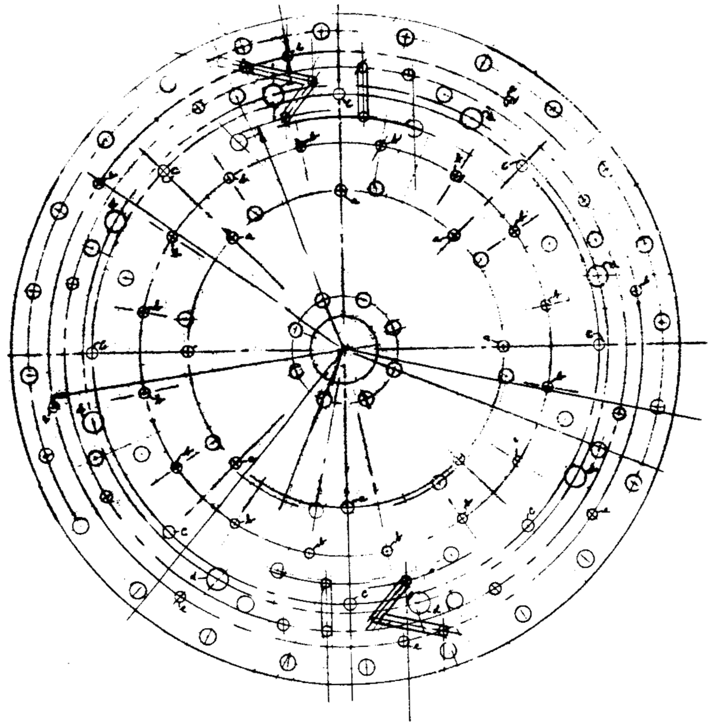


FIGURE 3-15(a) TEST TRANSFER PLATE, NPX-104-64, BOTTOM

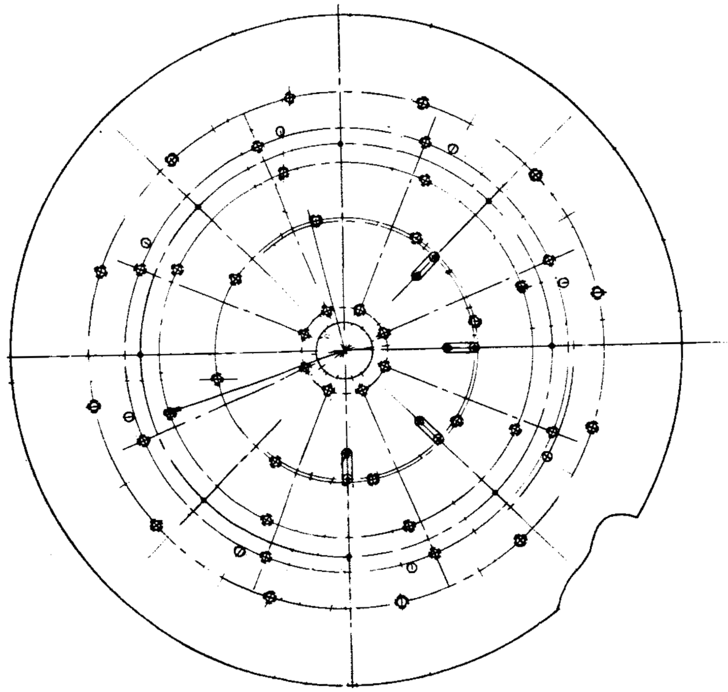


FIGURE 3-15(b) TEST COVER PLATE, NPX-104-66, TOP

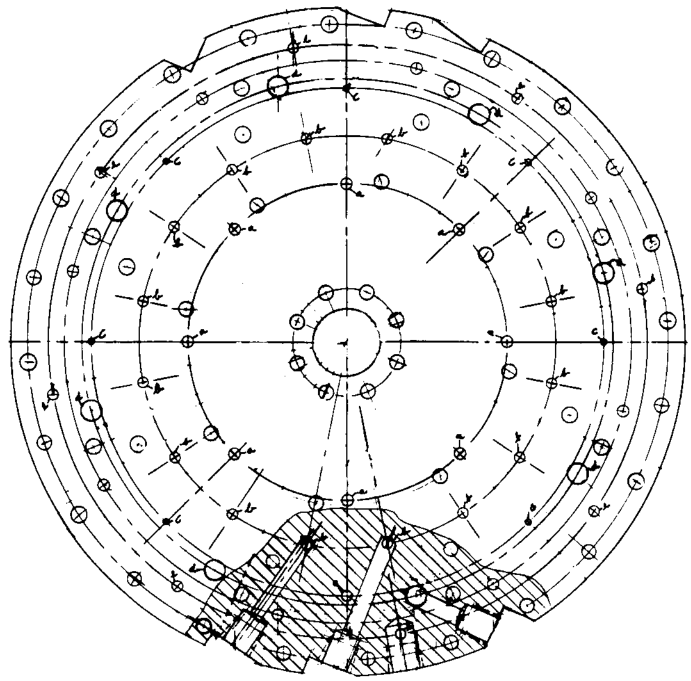


FIGURE 3-16(a) POWER VALVE TEST PLATE, NPX-104-63, BOTTOM

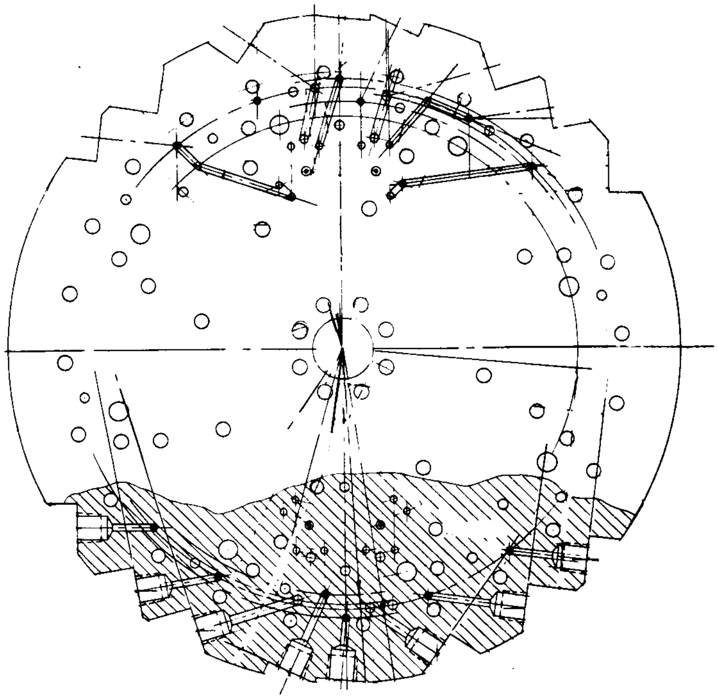


FIGURE 3-16(b) POWER SELECTOR VALVE TEST PLATE, NPX-104-65, BOTTOM

SECTION 4

THIRD QUARTER GOALS

4.1 MECHANICAL COMPONENTS

1. Assemble actuator-motor and rework as required.

2. Test actuator in accordance with the applicable Engineering Project Instructions to determine the motor static and dynamic characteristics.

3. Incorporate the commutation circuitry and commence complete actuator-motor evaluation.

4.2 COMMUTATION CIRCUITRY

1. Assemble and test the complete circuitry.

2. Develop and incorporate the directional amplifier and the pressure error valve.

4.3 ANALYTICAL STUDIES

1. Commence analysis of actuator-motor performance and compare performance with conventional actuator motors.

2. Commence an analysis of the required closed loop compensation.

APPENDIX A

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